YOUR GLOBAL MOBILITY
ENGINEERING EXPERTS

ADDITIVE MANUFACTURING DESIGN AND AUTOMATED PROCESS DEVELOPMENT FOR A ROBOTIC VEHICLE CHASSIS PART IN AHEADD® CP1

RICHARD KORDAß, EDAG | SYAM UNNIKRISHNAN, CONSTELLIUM | THOMAS TÖPPEL, FRAUNHOFER-IWU

Constellium EDAG
Fraunhofer IWU

OUR
UNIQUE SELLING POINT

The **EDAG Group** is a leading independent **engineering services provider** that combines **excellent engineering** with the latest technological trends. Interdisciplinary teams of experts create unique **mobility** and **industry solutions** – globally and at the same time close to the customer.

OUR
FACTS & FIGURES

1969
FOUNDATION

~ 70
LOCATIONS WORLDWIDE

19
COUNTRIES

~ 9.000
EMPLOYEES

2015
IPO

~ 4 %
TRAINING RATE

844,3
MILLION REVENUE

~ 3,6 %
CAPITAL EXPENDITURE ON REVENUE

EDAG WORLDWIDE

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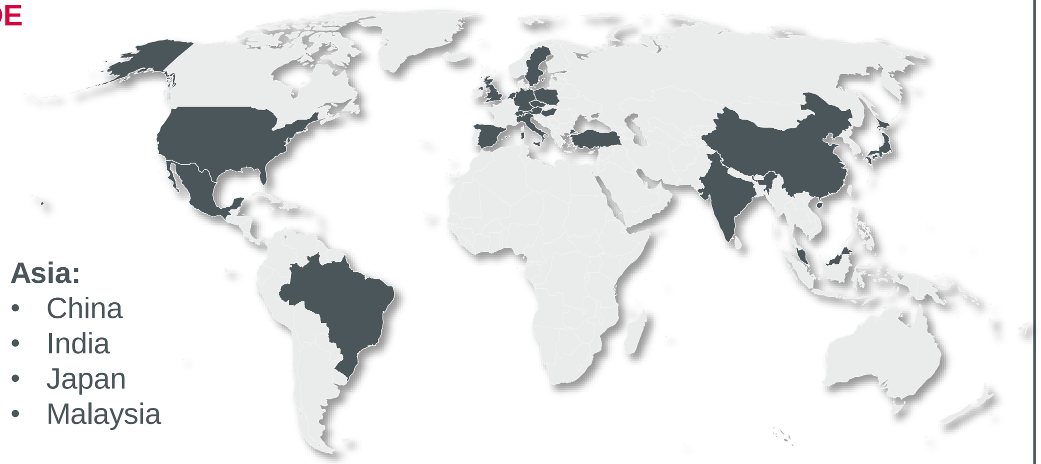
- Italy
- Netherlands
- Poland
- Sweden
- Switzerland
- Spain
- Czech Republic
- Turkey
- Hungary
- Austria

Asia:
- China
- India
- Japan
- Malaysia

North & South America:
- Brazil
- Mexico
- USA



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- Bremen
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- Köln
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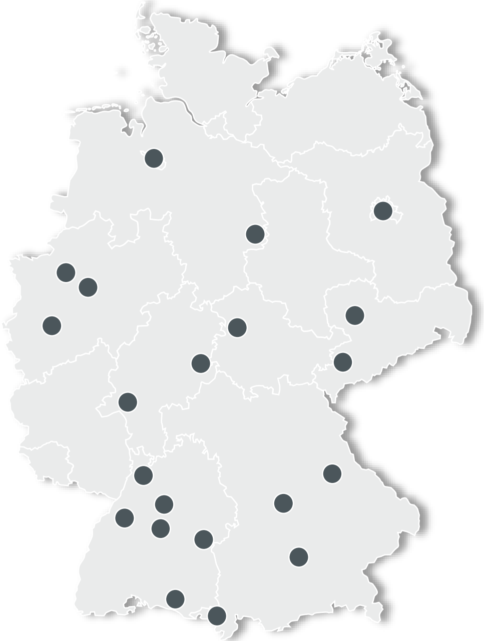
- Neckarsulm
- Recklinghausen
- Regensburg
- Stuttgart
- Ulm
- Weinheim
- Wiesbaden
- Wolfsburg
- Zwickau



OUR
RANGE OF SERVICES

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- Styling & Design
- Energy Systems and Drivetrain
- Vehicle Integration
- Body in White
- Chassis
- Interior & Exterior
- Aftersales Solutions

Electrics / Electronics
- Vehicle Electrics & Electronics
- Comfort & Body Systems
- Autonomous Drive & Safety
- Connectivity & User Experience
- Functional Safety
- Process Consulting
- Automotive Cybersecurity
- Process & Product Data Management

360° VEHICLE ENGINEERING

360° PRODUCTION ENGINEERING

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- Mobility Software
- Connected Services
- Smart City
- Smart Factory

Production Solutions
- Feasibility Analysis
- Production Planning
- Systems Engineering
- Fixture Technology
- Plant Automation
- Production Optimisation
- Safety Engineering Services

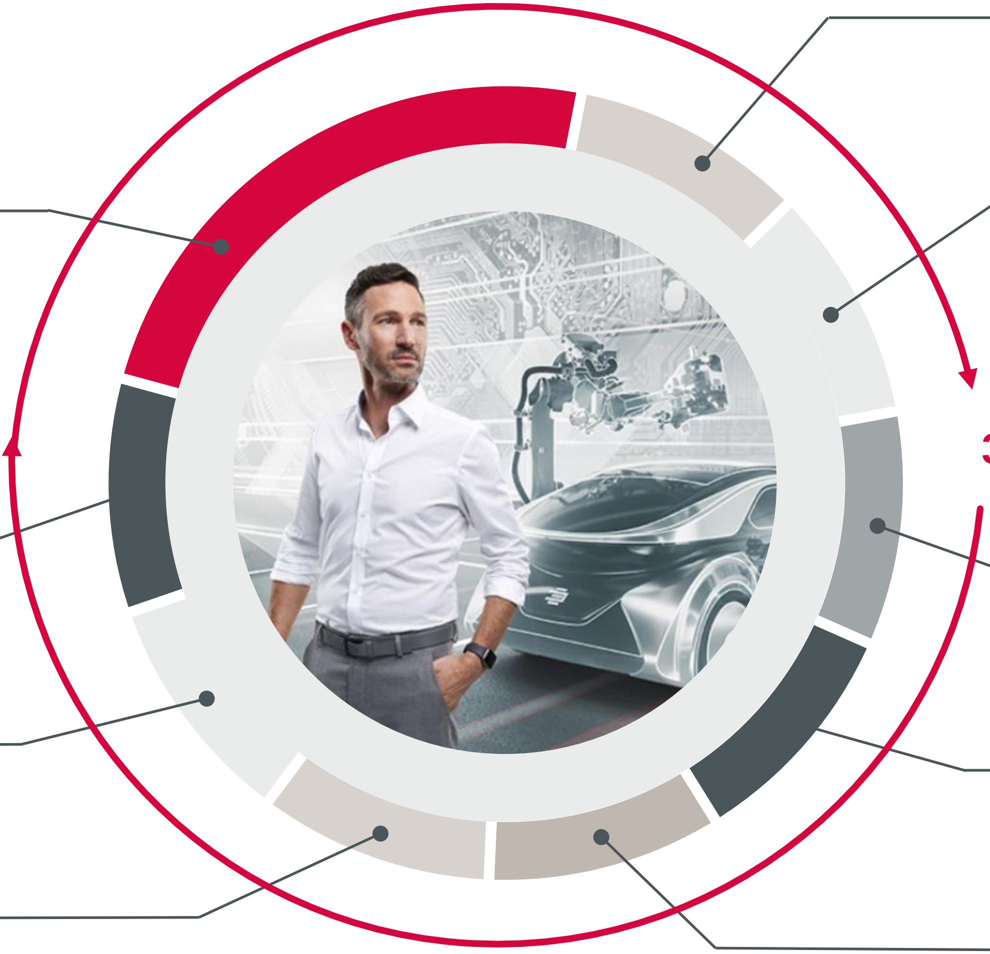
OUR
INDUSTRIAL EXPERTISE

MOTOR VEHICLES

COMMERCIAL VEHICLES AND OFFROAD

SPECIAL PURPOSE AND EMERGENCY VEHICLES

DEFENSE



MOTORCYLE

BICYCLE AND PEDELEC

360° INDUSTRIAL EXPERTISE

AEROSPACE

INDUSTRIAL SOLUTIONS

SMART CITIES

24/7 OPERATION TIME

VARIOUS ADD-ON MODULES / GADGETS
EFFICIENT AND PROFITABLE

On average, a private car is only driven for **one hour a day**. This means that the average car stands around unused for 23 hours a day, taking up valuable space, especially in cities.*

*Umweltbundesamt: https://www.umweltbundesamt.de/themen/verkehr/nachhaltige-mobilitaet/car-sharing#umweltvorteile-von-car-sharing

Funded by:

Federal Ministry for Digital and Transport

on the basis of a decision by the German Bundestag

Projektträger

Bund für V

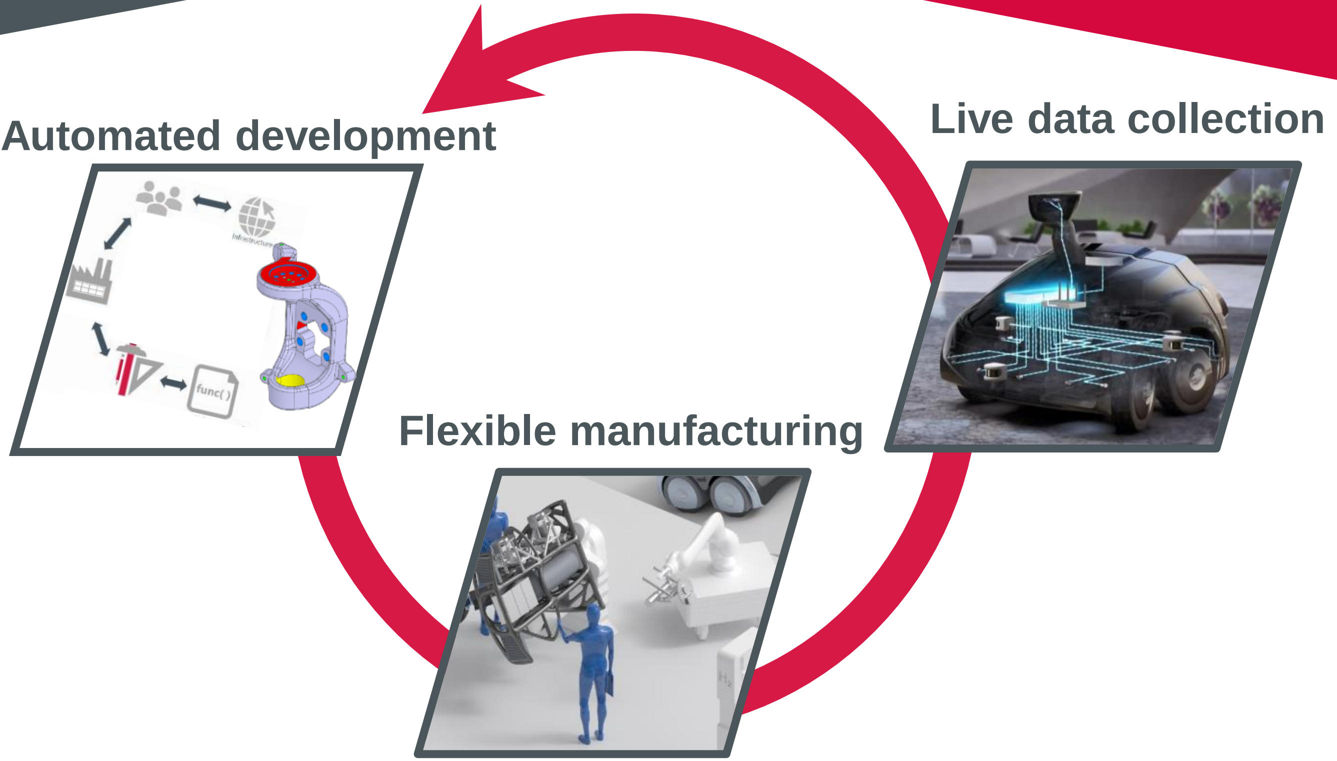
USE CASE
WHEEL CARRIER CITYBOT

Current situation

- Different usage scenarios
- High load variations
- High requirement variants
- "Rigid" specifications
- Improvement necessary for economic and environmental sustainability
- Component development time ≈ Several weeks / months

Advantages of automation

- Geometry adjustments automatically generated for different scenarios
- Closed Loop Engineering applicable
- Dynamic specifications
- Economic and environmental sustainability improvement
- Reduction of component development time



MOTIVATION

Goal

Automation of the development of a Cornermodule in the Citybot project

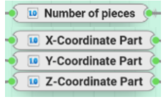
Collected loads

Requirements

Synera

Manufacturing process selection

- Die casting
- Sand casting
- Investment casting
- Permanent mold casting
- Selective laser melting
- Milling



Optimal MP*

Optimal geometry

*Manufacturing Process

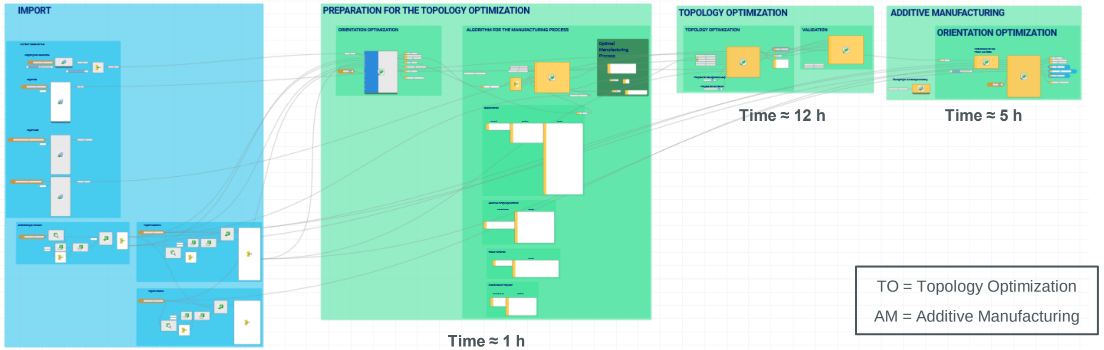
4 phases (time ≈ 18h) → **shortened by factor 40**

Phase 1 - Import

Phase 2 - Preparation TO

Phase 3 - TO

Phase 4 - AM preparation



Time ≈ 1 min

Time ≈ 1 h

Time ≈ 12 h

Time ≈ 5 h

TO = Topology Optimization
AM = Additive Manufacturing

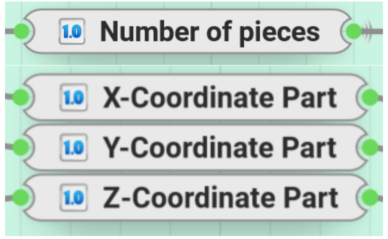
TO PREPARATION

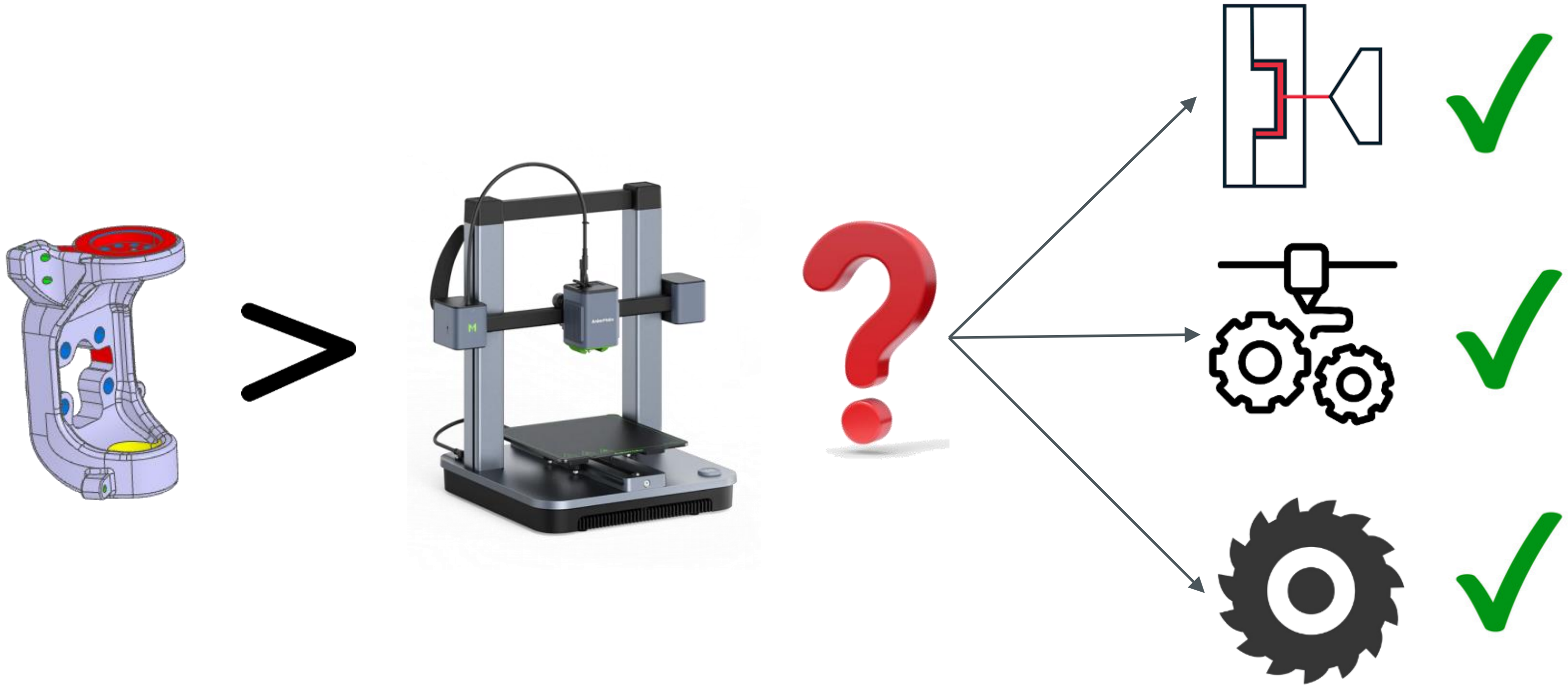
MANUFACTURING ALGORITHM

- Considering manufacturing processes according to their feasibility
  - E.g. filter for checking the size of part
- Considering the the number of pieces and comparing the costs

Manufacturing process for selection

- Die casting
- Sand casting
- Investment casting
- Permanent mold casting
- Selective laser melting
- Milling





CITYBOT LOAD DATA DETERMINATION
STATIC EQUIVALENT LOADS FROM MEASURED DATA

Available measurement data

- Max. Vertical acceleration: 23m/s^2
- Max. Longitudinal acceleration: -10.5m/s^2
- Max. Transverse acceleration: 9.6m/s^2

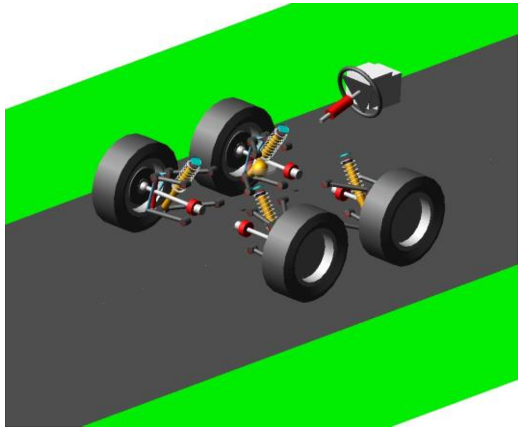
Corresponding dynamic maneuvers

- Sleeper crossing with approx. 5km/h
- Max. Braking from approx. 12km/h
- Slalom drive with approx. 15km/h

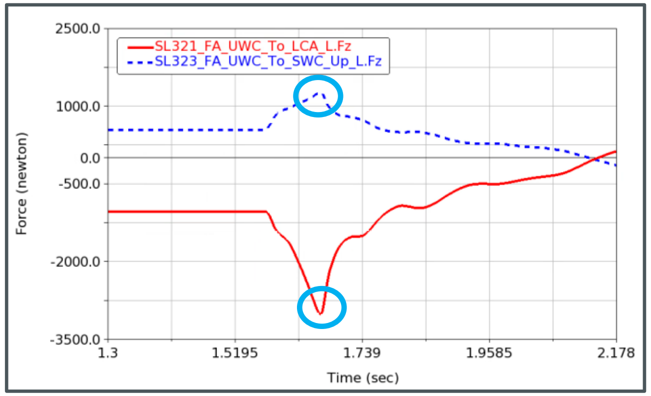
Measurement conditions

- 100Hz sampling no pre-filtering
- Low speeds: little "impact
- Extraction of the individual maneuvers necessary

Utilization of the measurement data in the multi-body simulation



Determination of the extreme points from the simulated load-time series



Excel of the static equivalent loads as a handover document

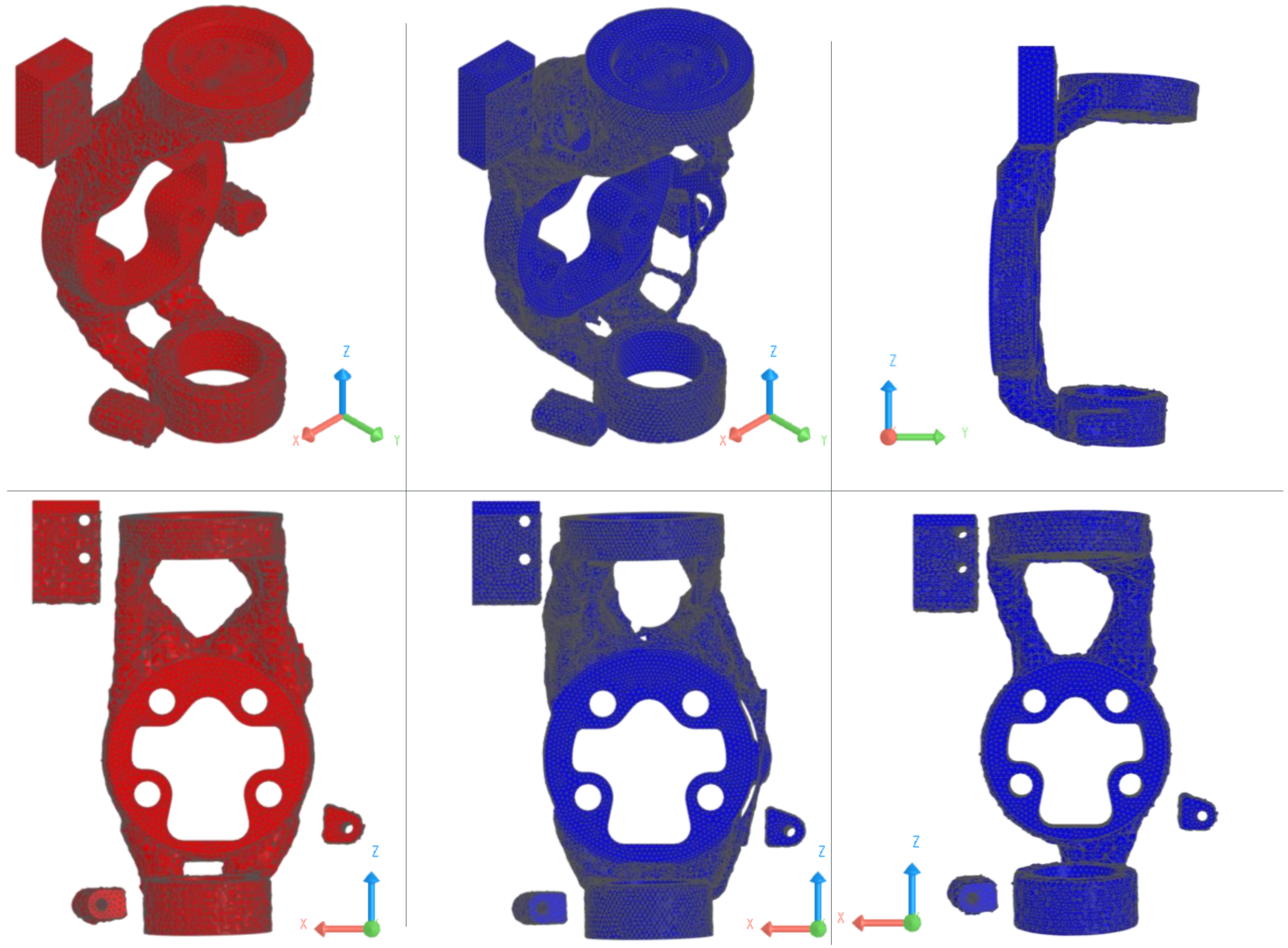
Position	Fx[N]	Fy[N]	Fz[N]	Mx[Nmm]	My[Nmm]	Mz[Nmm]
SL301_FA_LCA_To_SbFr_Front_L	-284	2493	466	329	-285	-2148
SL302_FA_LCA_To_SbFr_Front_R	-283	-2480	466	-327	-285	2148
SL303_FA_LCA_To_SbFr_Rear_L	-242	816	575	329	-285	-2148
SL304_FA_LCA_To_SbFr_Rear_R	-241	-815	575	-327	-285	2148
SL305_FA_LCA_To_Damper_L	88	-2205	-3187	3057	-662	503
SL306_FA_LCA_To_Damper_R	88	2205	-3187	-3058	-662	-503
SL307_FA_LCA_To_UWC_L	524	-1169	2392	0	0	0
SL308_FA_LCA_To_UWC_R	524	1169	2392	0	0	0
SL309_FA_UCA_To_SbFr_Front_L	-503	-1471	-372	151	-261	-1165
SL310_FA_UCA_To_SbFr_Front_R	-503	1467	-371	-151	-259	1167
SL311_FA_UCA_To_SbFr_Rear_L	-639	-2065	-443	151	-261	-1165
SL312_FA_UCA_To_SbFr_Rear_R	-639	2064	-443	-151	-259	1167
SL313_FA_UCA_To_UWC_Front_L	573	-1676	-701	113	-1261	3892
SL314_FA_UCA_To_UWC_Front_R	573	1678	-701	-113	-1259	-3889
SL315_FA_UCA_To_UWC_Rear_L	570	2852	859	113	-1261	3892
SL316_FA_UCA_To_UWC_Rear_R	570	-2847	857	-113	-1259	-3889

INPUT OF LOADS VIA DRIVING MANEUVERS

	High Speed, high load	Medium Speed, high load	Low Speed, low load
Event	Velocity [km/h]		
EV01_Slalom	35	15	5
EV05_Braking_forward	50	12	10
EV06_Acceleration	45	-	-
EV08_Bump	20	5	3
EV09_Pothole	15	-	-

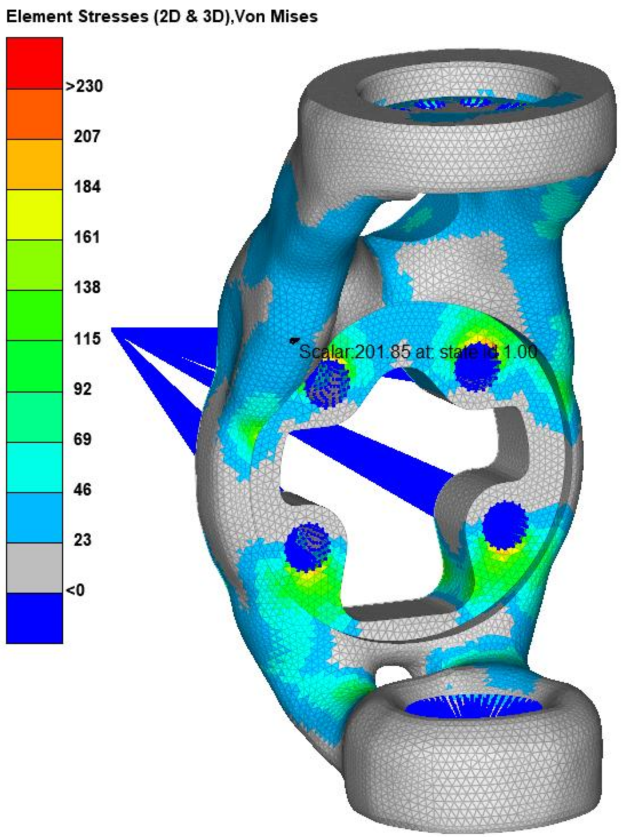
RESULTS OF TOPOLOGY OPTIMISATION
COMPARISON

High Speed, high load	Medium Speed, high load	Low Speed, low load

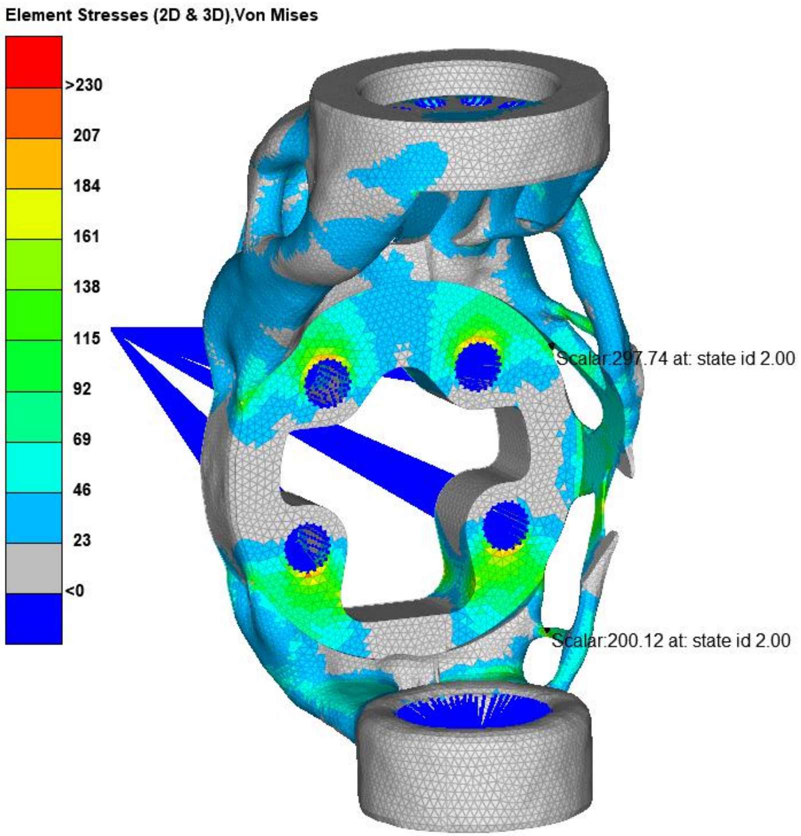


VALIDATION CALCULATION
COMPARISON

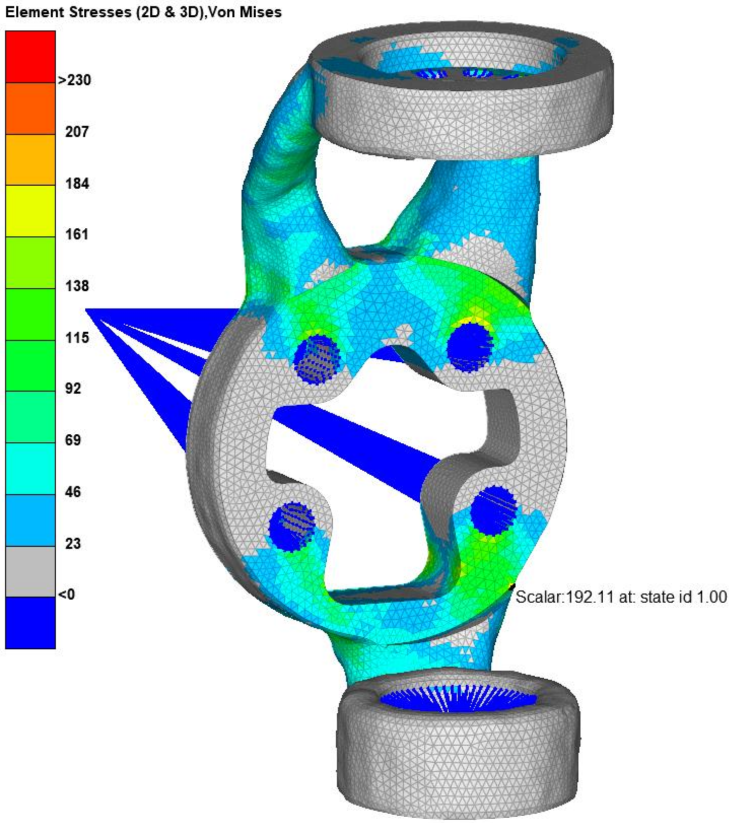
High Speed, high load



Medium Speed, high load

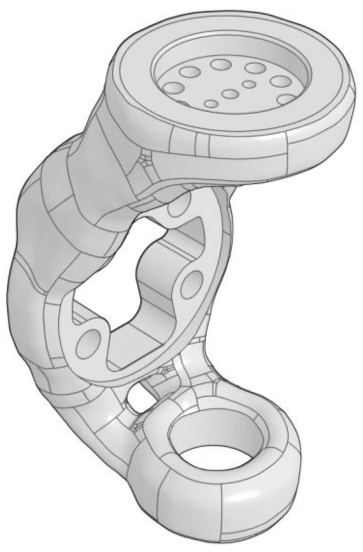


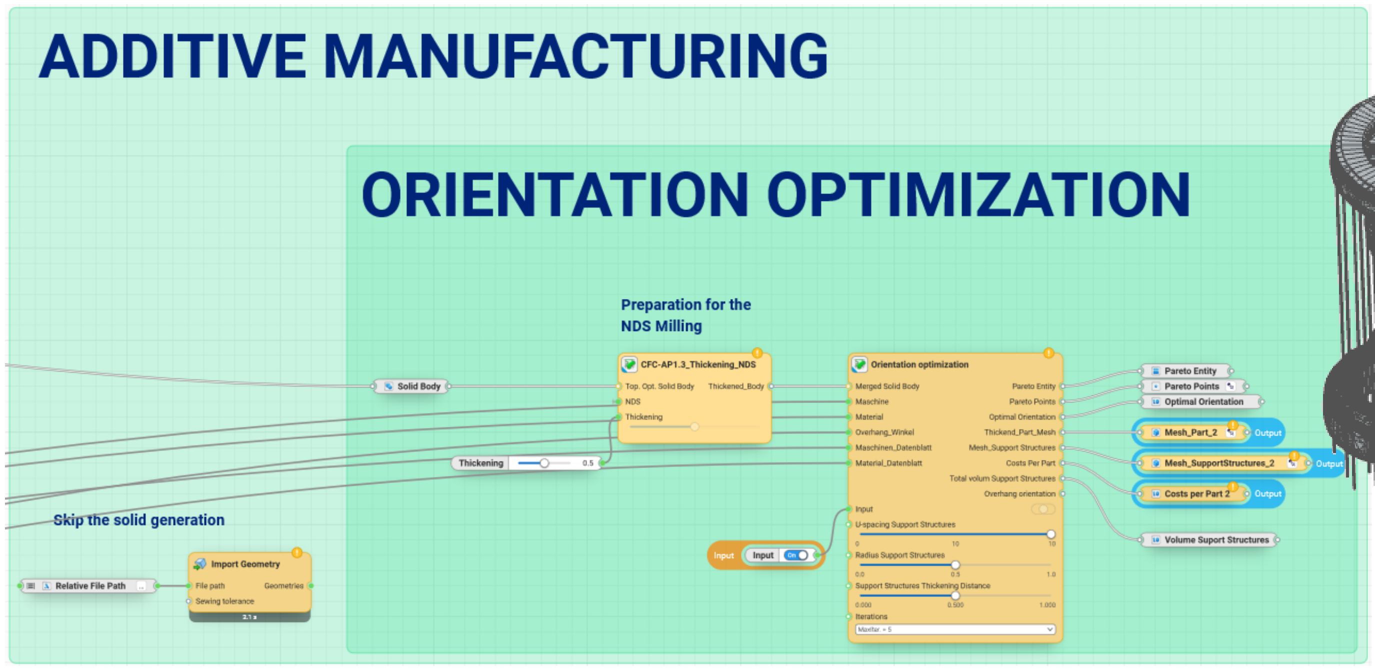
Low Speed, low load

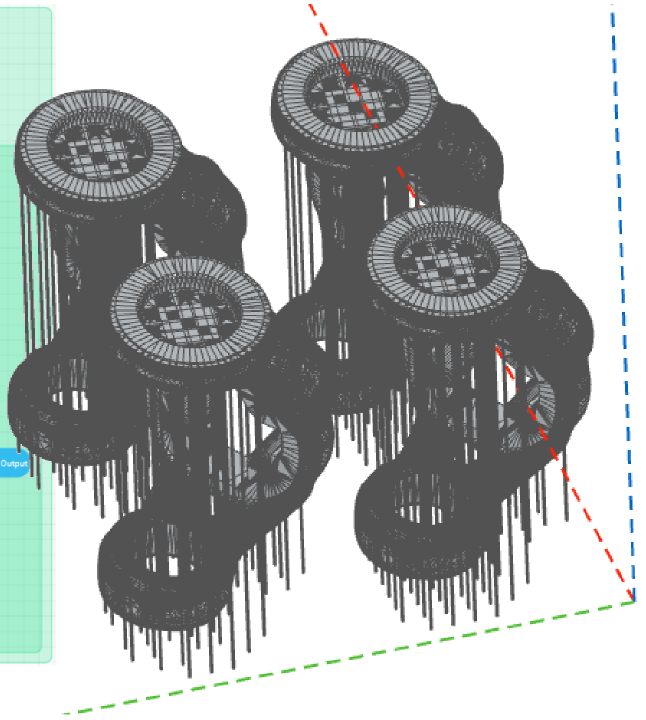


AM OPTIMISATION

- thickening of the "NDS" for later mechanical treatment
- alignment optimization, so that the surfaces can be milled
- Determination of support structures, thickening and the total cost

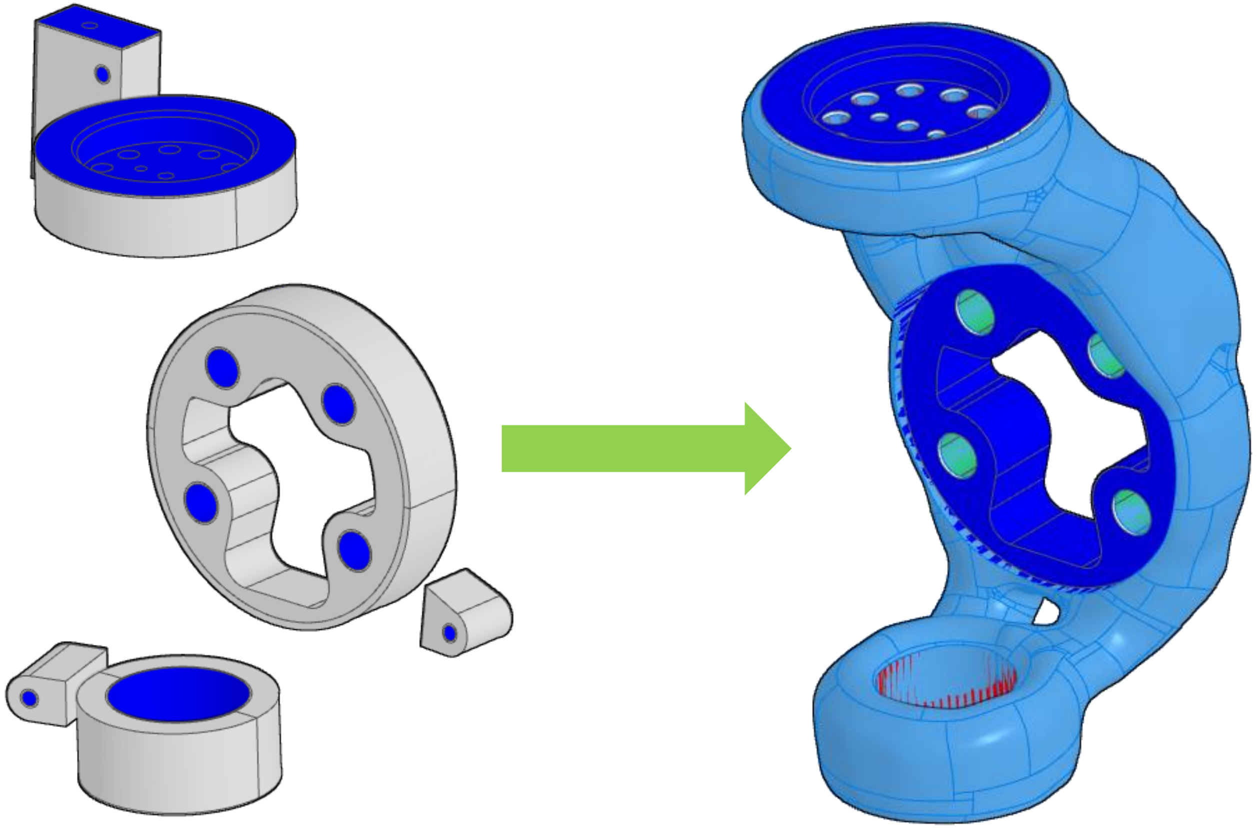






AM POSTPROCESSING OPTIMISATION

- Thickening of functional surfaces which have to be milled
- Combining functional surfaces with the topology-optimized geometry



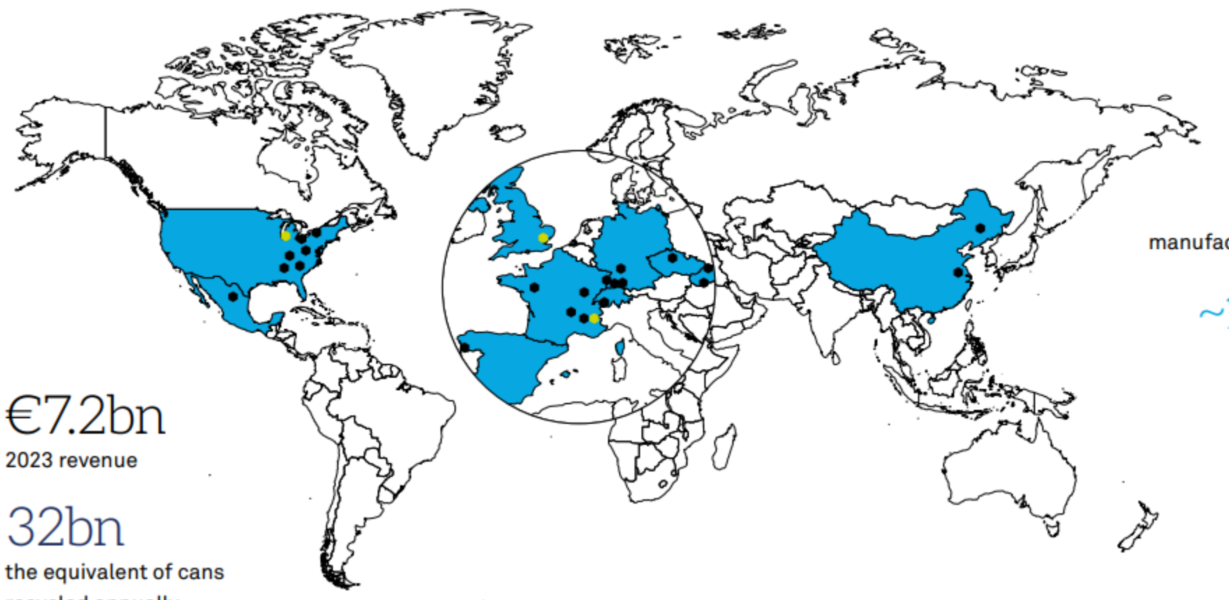
Constellium Aheadd® : Aluminium Alloys Designed for Laser Powder Bed AM to Improve Properties and Processing Performance

C-TEC Constellium Technology Center, France

Syam UNNIKRISHNAN
Business development Manager

Constellium

Constellium at a glance



25
manufacturing facilities

~12,000
employees

3
R&D centers

€7.2bn
2023 revenue

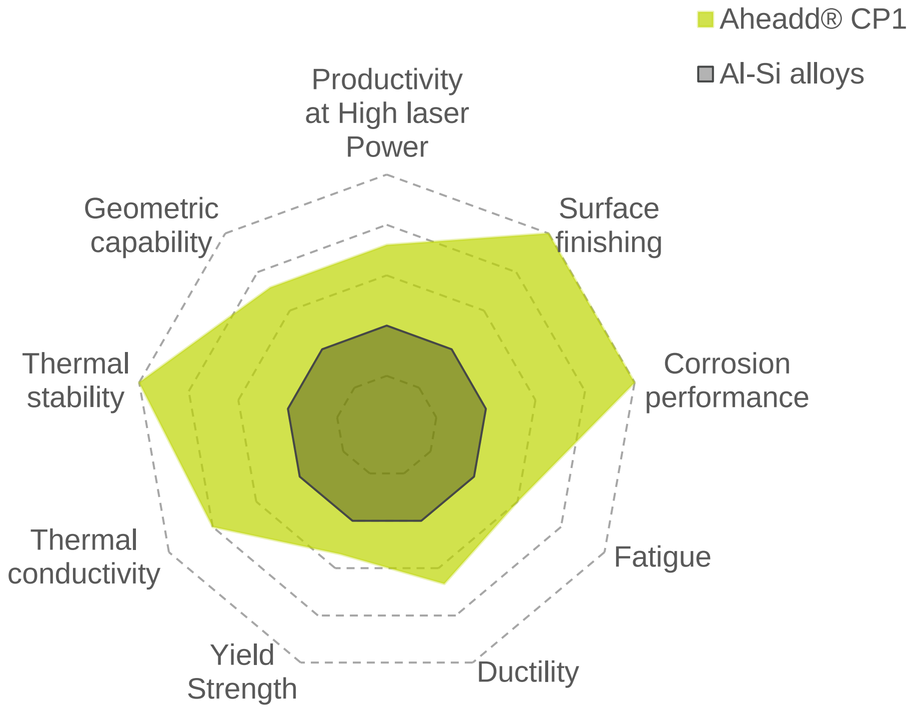
32bn
the equivalent of cans recycled annually

Aheadd® CP1 – An Alu. Alloy exclusively designed for LPBF process

Al	Zr	Fe
Aluminum	Zirconium	Iron

Alloy AA8A61.50

Heat Treatment at 400°C	Typical properties, room temperature (vertical direction)			Thermal Conductivity W/m.K	Electrical Conductivity MS/m (%IACS)
	YS (MPa)	UTS (MPa)	A%		
0h	137	203	22.8	124	18.1 (31.2)
4h	323	342	12.8	187	28.4 (49.0)

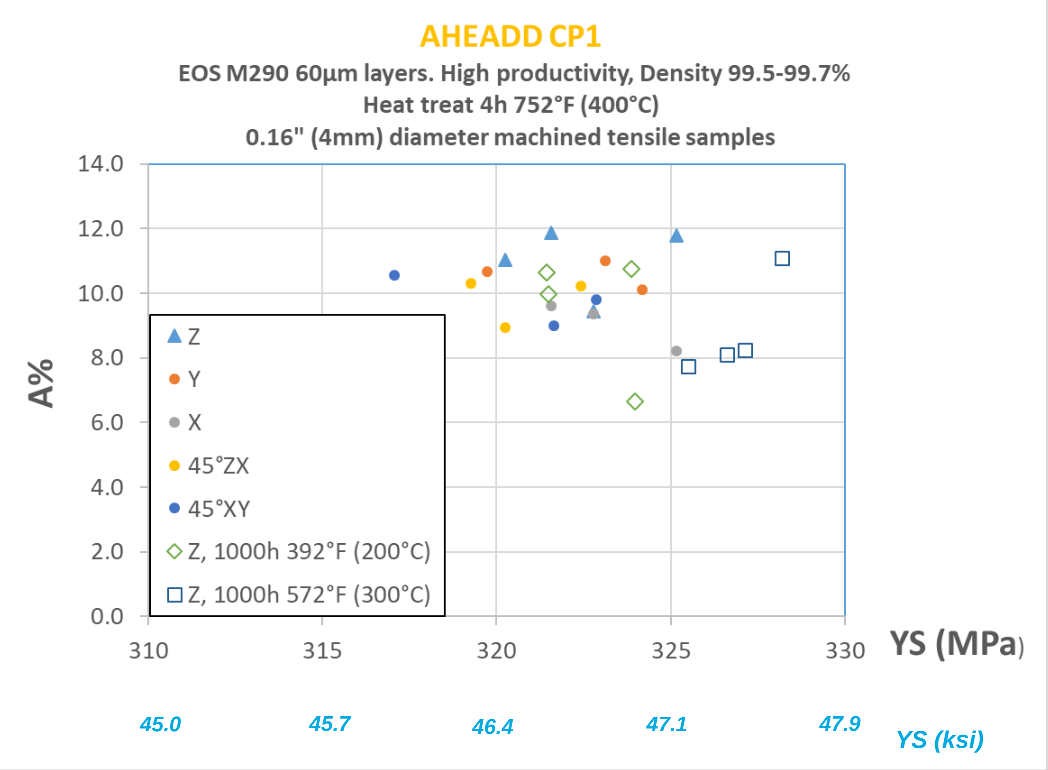


High Conductivity & High Productivity alloy

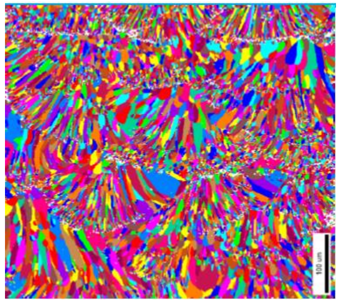
A drop-in AM solution for AlSi and 6061 based applications

Aheadd® CP1 – An LPBF alloy with well-balanced Properties, Printability and Post processing

- High thermal conductivity and good strength
- Thermally stable up to 1000 hrs 300°C
- Excellent corrosion resistance
- No volatile elements => Stable and Wide process window
- Low residual strength => large parts no risk of cracks
- Simple heat treatment => no Quench/solution treatment
- Almost no anisotropy => Better component design
- Various surface finishing option (Anodising, Chemical polishing etc).



High Quality anodising
(Decorative & Hard coating)

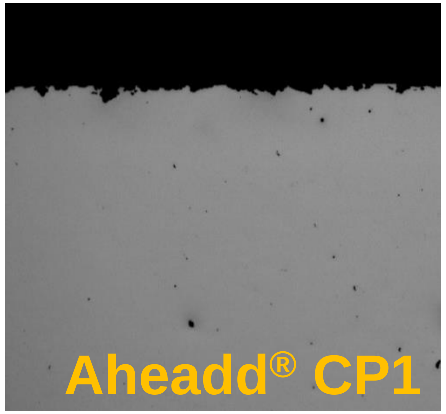


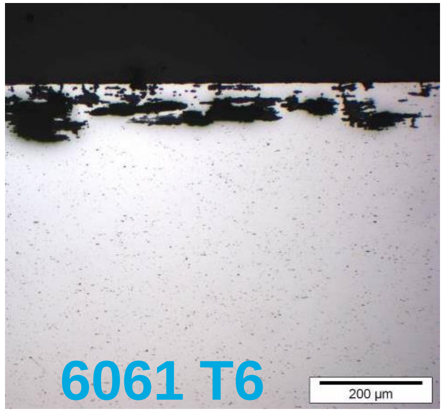
Fine grain structure
(Stable up to 300°C)

Laser power	Layer thickness	Productivity	Density
370W	60 µm	39 cm3/h	99.8%
650W	90 µm	78 cm3/h	99.7%
1000W	150 µm	164 cm3/h	99.5%

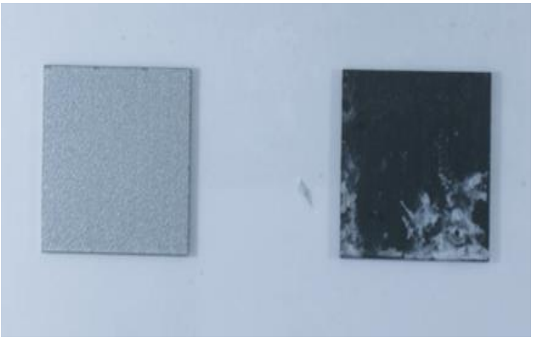
Wide Process window & Productivity

Aheadd® CP1 – Exceptional corrosion and stress-corrosion performance

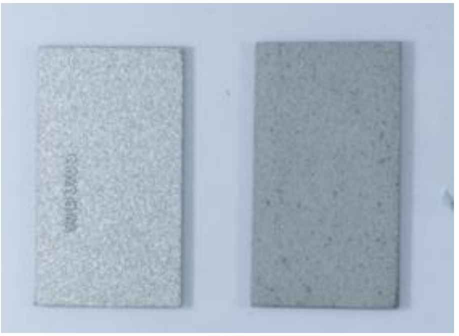




Corrosion test : ISO 11846B
24h immersion, 30g/L NaCl + 10ml/L HCl, 30°C



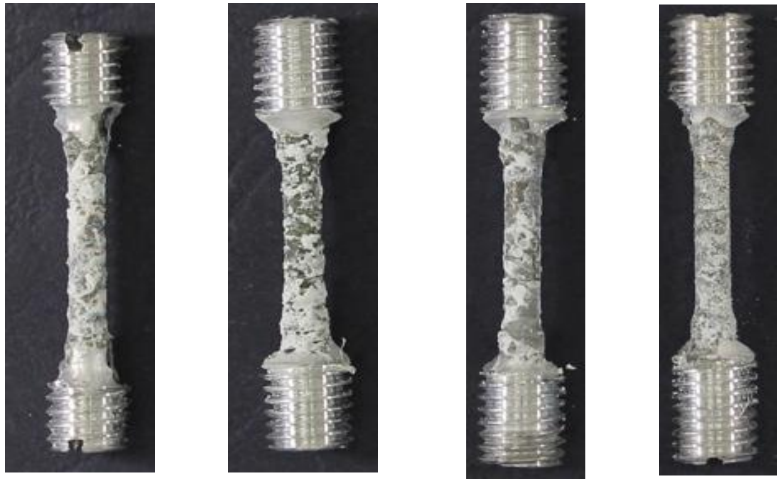
AlSi10Mg



Aheadd CP1

Salt Spray - 1 Month 35°C (ASTM B117)
Specimens printied in SLM 280

Aheadd® CP1
4h 400°C
<u>90 days</u> of ASTM G44 at 90% of yield strength



2024 (T8) 2219 (T87) 7010 (T7651) 7050 (T74)

Surface condition of conventional wrought alloys after 40 days exposure in ASTM G44 alternate immersion

Extreme stress corrosion testing (90 days at 90% of yield strength) :
Aheadd CP1 shows no significant corrosion

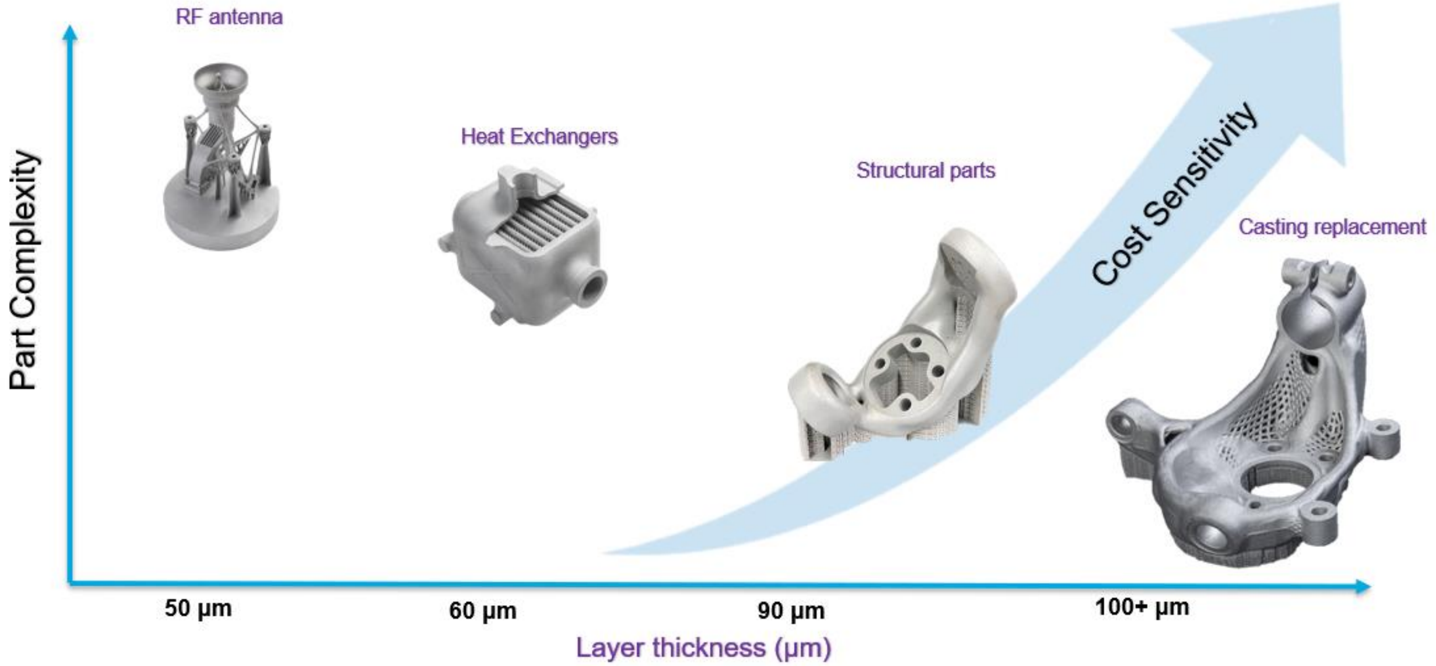
Aheadd® CP1-A single alum. alloy to cover wide range of applications

Prints faster

- No volatile elements
- Can print at high layer thickness
- Wide process window

Cost reduction

- High layer thickness build reduce the machine print time.
- No complex heat treatment (no quench or solution treatment).
- Highly ductile in as-built (> 22%)
- Very less rejection or print loss.



Large machines compatibility

- CP1 can be printed with high laser power such as 1KW.
- Highly compatible for machine with multiple lasers (no smoke during printing)

Ease of Scale-up/Industrialisation

- Simple alloy system (Al-Fe-Zr) & good economies of scale
- No rare earth/expensive elements
- Ease of machinability/ no ceramic phase.
- Inter gas atomised powder

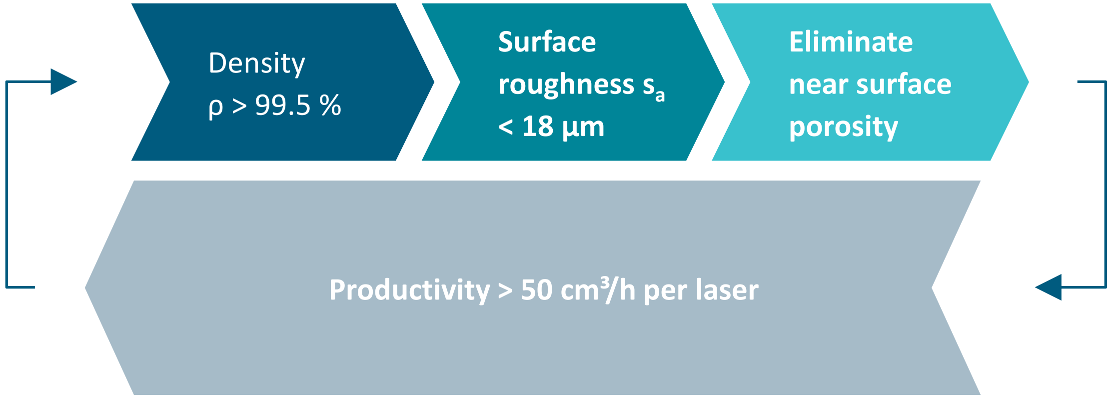
Functional Integration

- High thermal conductivity
- Good YS & elongation at break
- No anisotropy/robust properties
- Better corrosion resistance than AlSi
- Possibility to anodise & braze
- Thermally stability up to 1000 hrs, 300°C

Process Parameter Development for CP1 at Fraunhofer IWU Dresden

LPBF machine: TRUMPF TruPrint 5000

- 3x 500 W fiber laser, 80 µm min. focus
- Build envelope Ø 290 mm, H 400 mm



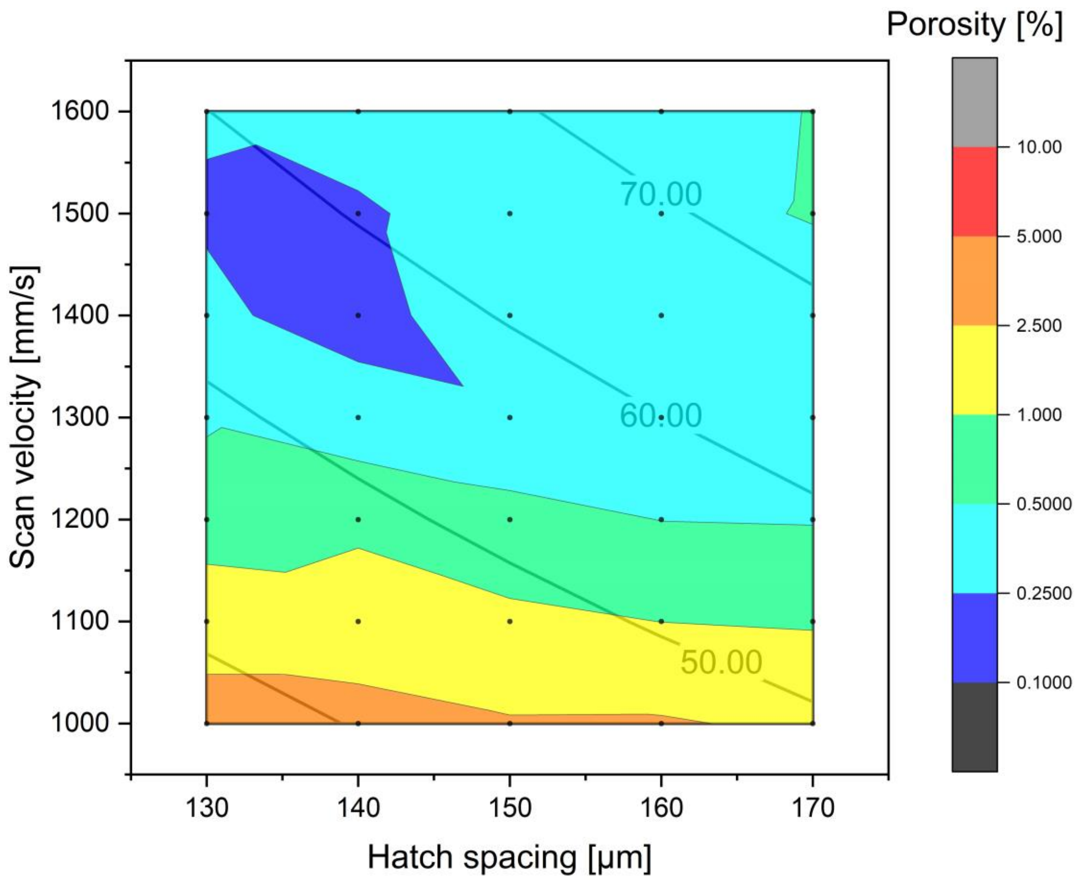
Defined goals for parameter development

- Setting up an initial parameter set with Design of Experiments (DoE)
- Various analysis techniques to determine the test results (metallography, 3D surface analysis, tensile testing)

Richard Kordaß, Syam Unnikrishnan, Thomas Töppel

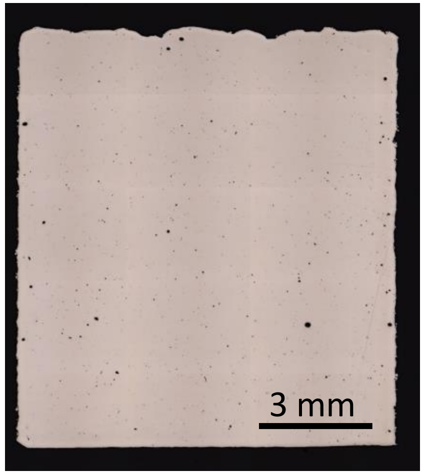
Fraunhofer IWU

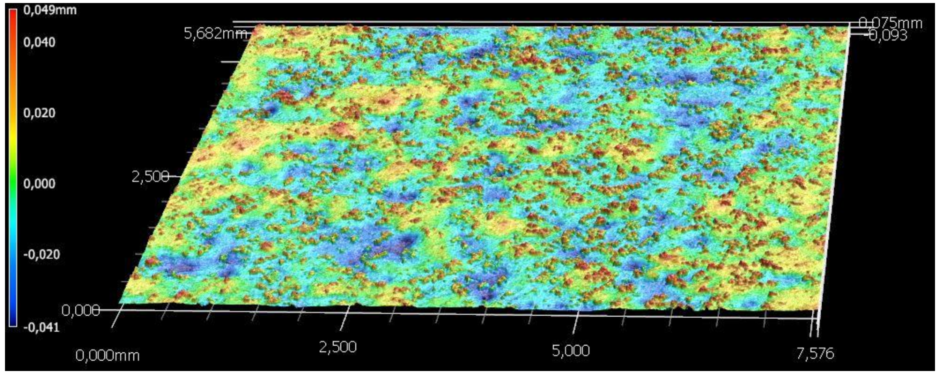
Results of the Parameter Development



Initial parameter setting with following results

- Density: ρ = 99.75 ± 0.05 %
- Surface roughness: S_a = 15 µm
- Layer thickness: 80 µm
- Productivity: 60 cm³/h per laser





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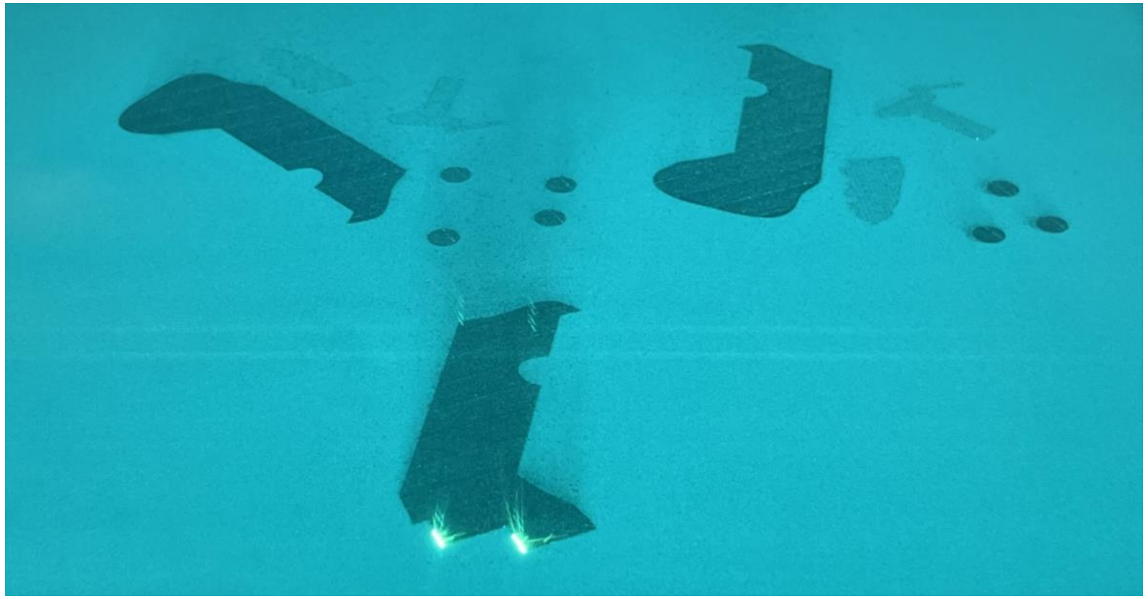
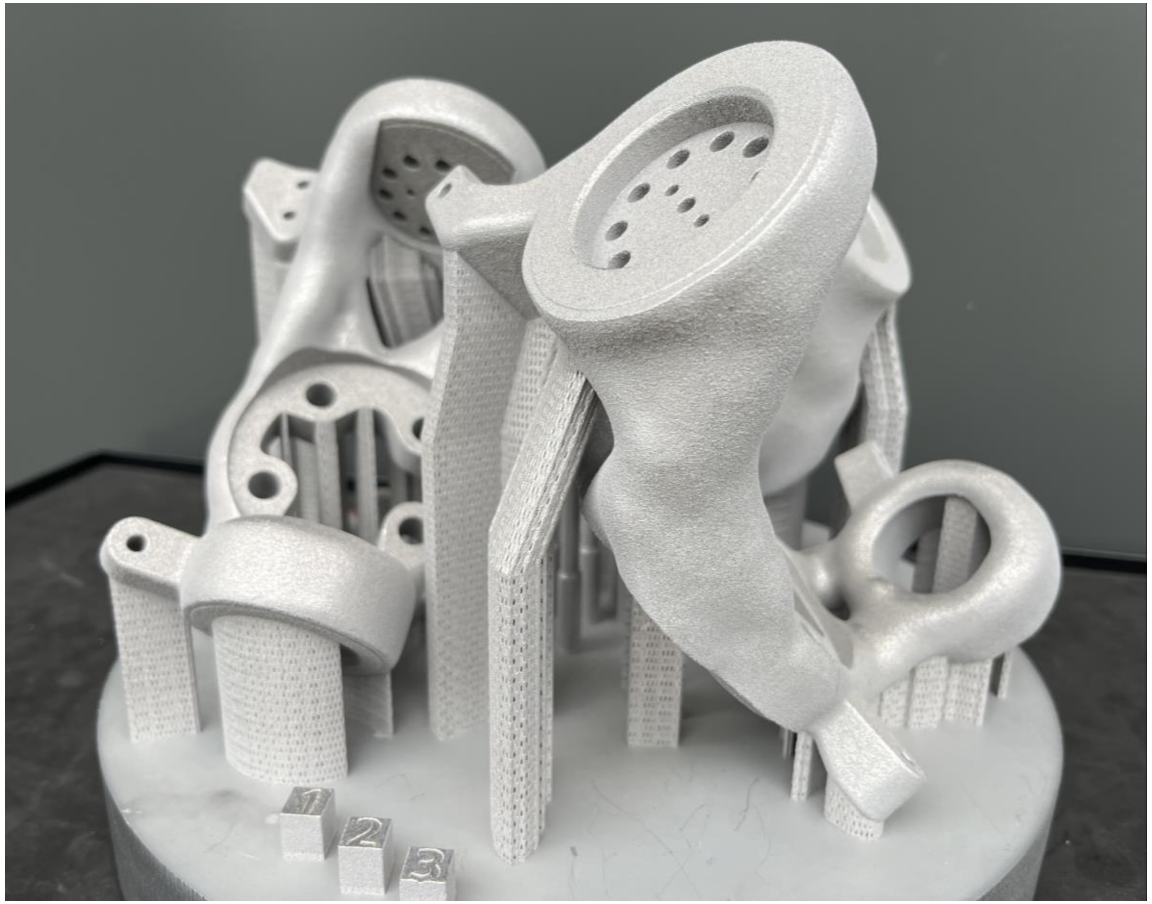
CityBot Wheel Carrier Manufacturing

LPBF manufacturing on TRUMPF TruPrint 5000

- 3 parts per build job (plus test cubes and tensile specimens)
- 3 lasers in production
- 18 hours build duration with real a build rate of 67 cm³/h





Richard Kordaß, Syam Unnikrishnan, Thomas Töppel 16.05.2024
presentation at Rapid.Tech 2024 only

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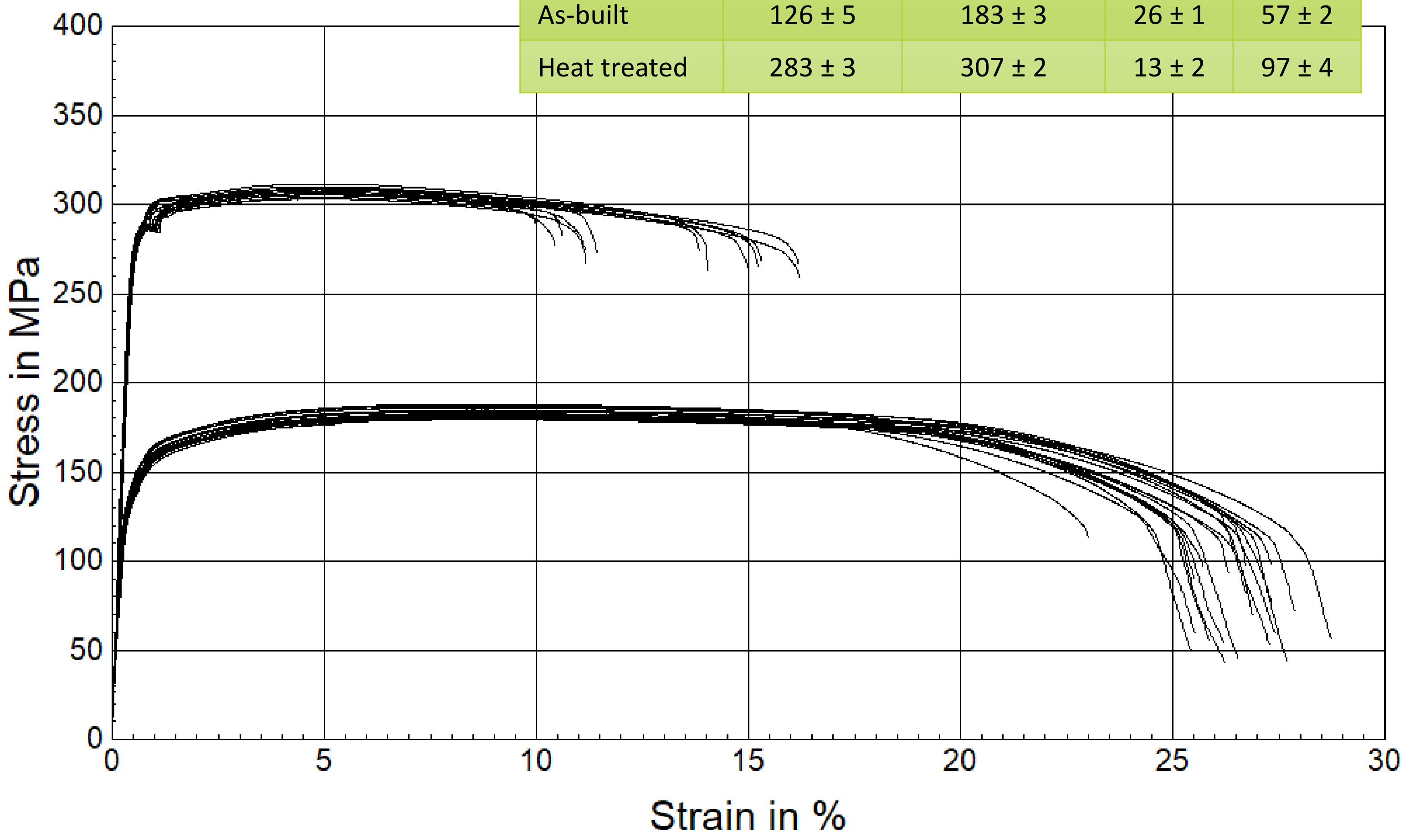
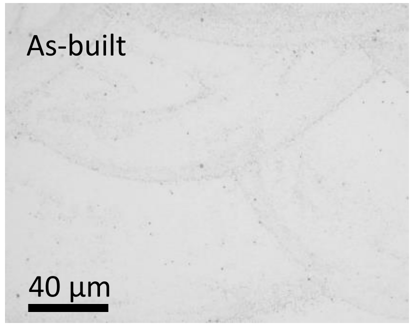
CityBot Wheel Carrier Manufacturing

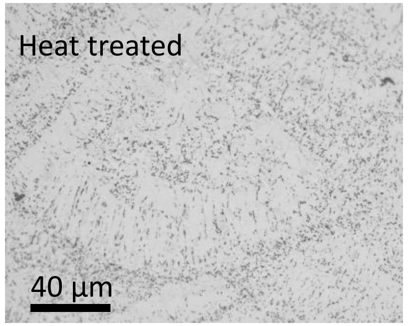


Condition	YS in MPa	UTS in MPa	A in %	HV
As-built	126 ± 5	183 ± 3	26 ± 1	57 ± 2
Heat treated	283 ± 3	307 ± 2	13 ± 2	97 ± 4

Tensile and hardness testing

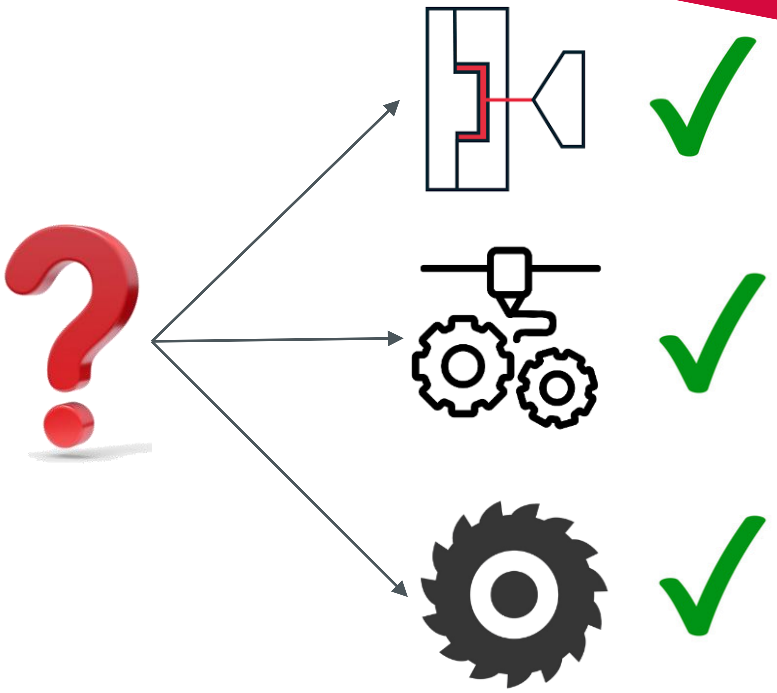
- 4 build jobs
- 20+20 samples w./wo. heat treatment
  - HT: 4h @ 400 °C under air
- Tensile bars acc. DIN 50125 A 6 x 30 (as-built surface, not machined)
- DIN EN ISO 6892-1 (Method B)
  - Elastic part: 8 MPa/s
  - Plastic part: 0,005 1/s
- Vickers hardness acc. DIN EN ISO 6507

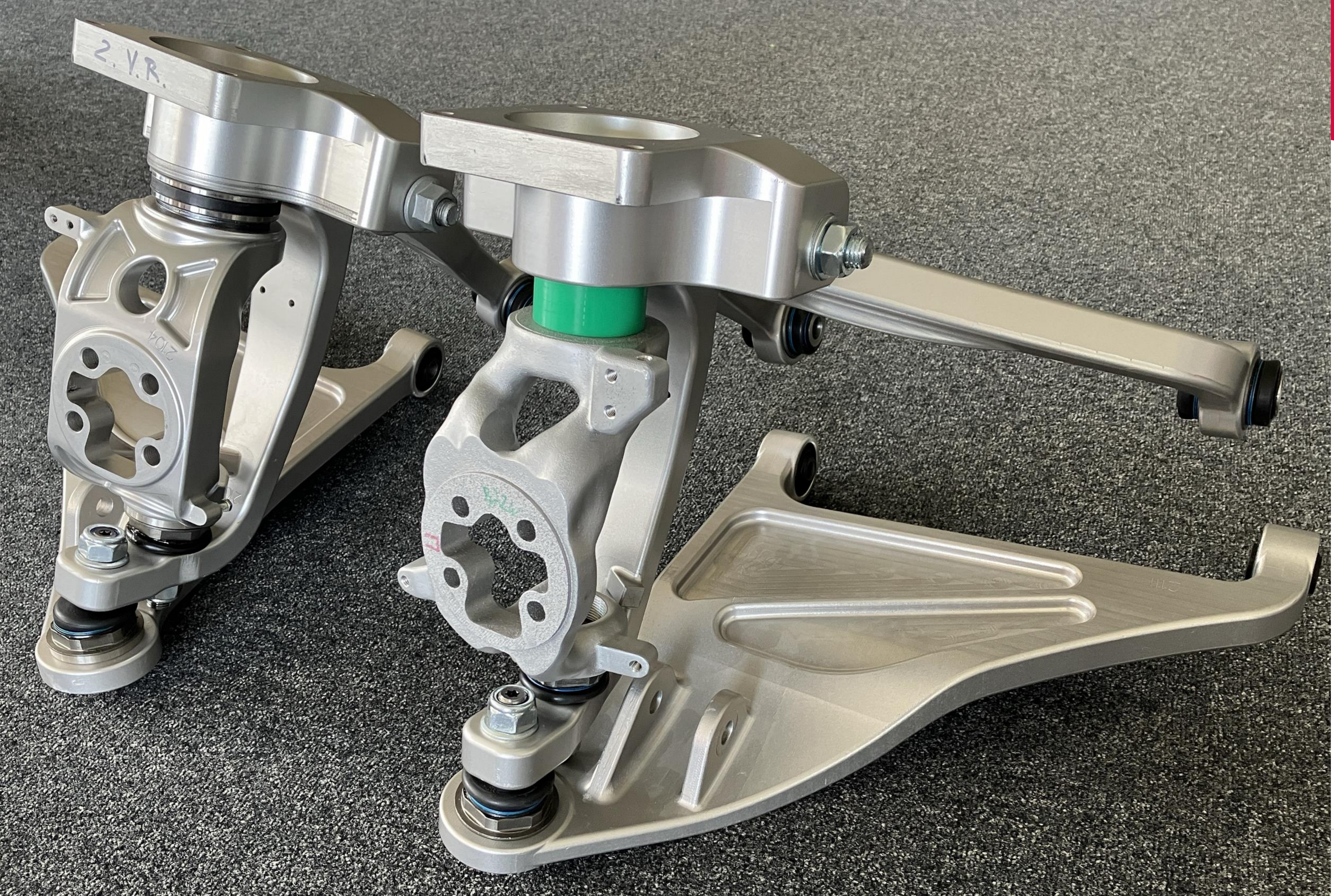




AM POSTPROCESSING OPTIMISATION

- Thickening of functional surfaces which have to be milled
- Combining functional surfaces with the topology-optimized geometry





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Let's transform automotive development together!

@ richard.kordass@edag.com

Richard Kordaß