VTT 3DMetalprint

Joni Reijonen, VTT

3D-vallankumouspäivä
12.3.2019
Vossi Group, Tampere

Opportunities in the world of huge challenges

Growth with sustainable innovations

Climate action
Clean energy for the future

Resource sufficiency
Prosperity from resource wisdom

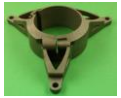
Industrial renewal
Innovations empowering industry

Good life
Improved quality of life and work

Safety and security
Resiliency in turbulent world

Experimental facilities

From powder to product – agile pilots



Material & component testing

Post processing

Direct Write Technology

Selective Laser Melting

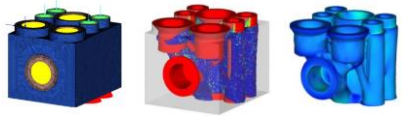
Powder characterization

Plasma spheroidization

Gas atomization

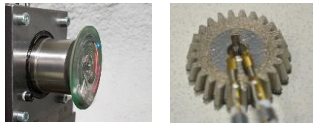
Application Services

Competitive products & new business models



Design for AM

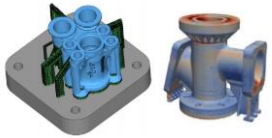
Digital spare parts



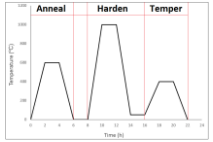
Added intelligence & functionality

Production Services

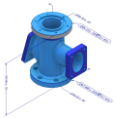
Increased productivity & quality

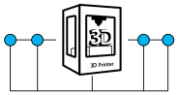


Thermal distortions mitigation



Post-processing

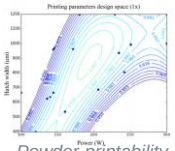




Integration of AM into production

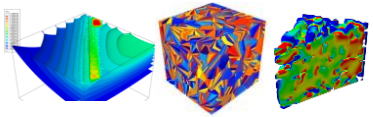
Material Services

Increased quality & material performance



Powder printability

Application driven materials



Virtual material factory

Application services

Hydraulic valve block

66 % lighter
no leaks
optimized flow

Impact

”When we saw hydraulic block by VTT we understood it is feasible and sensible”

Valeria Tirelli, CEO at AIDRO Hydraulics & 3D printing

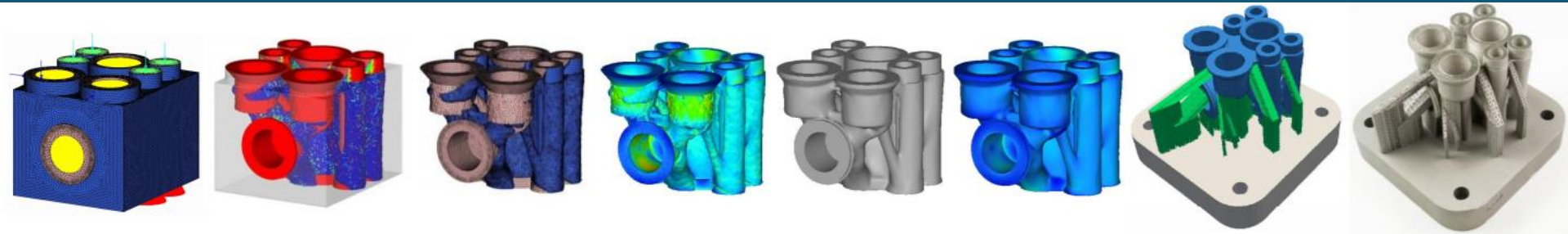
aidro

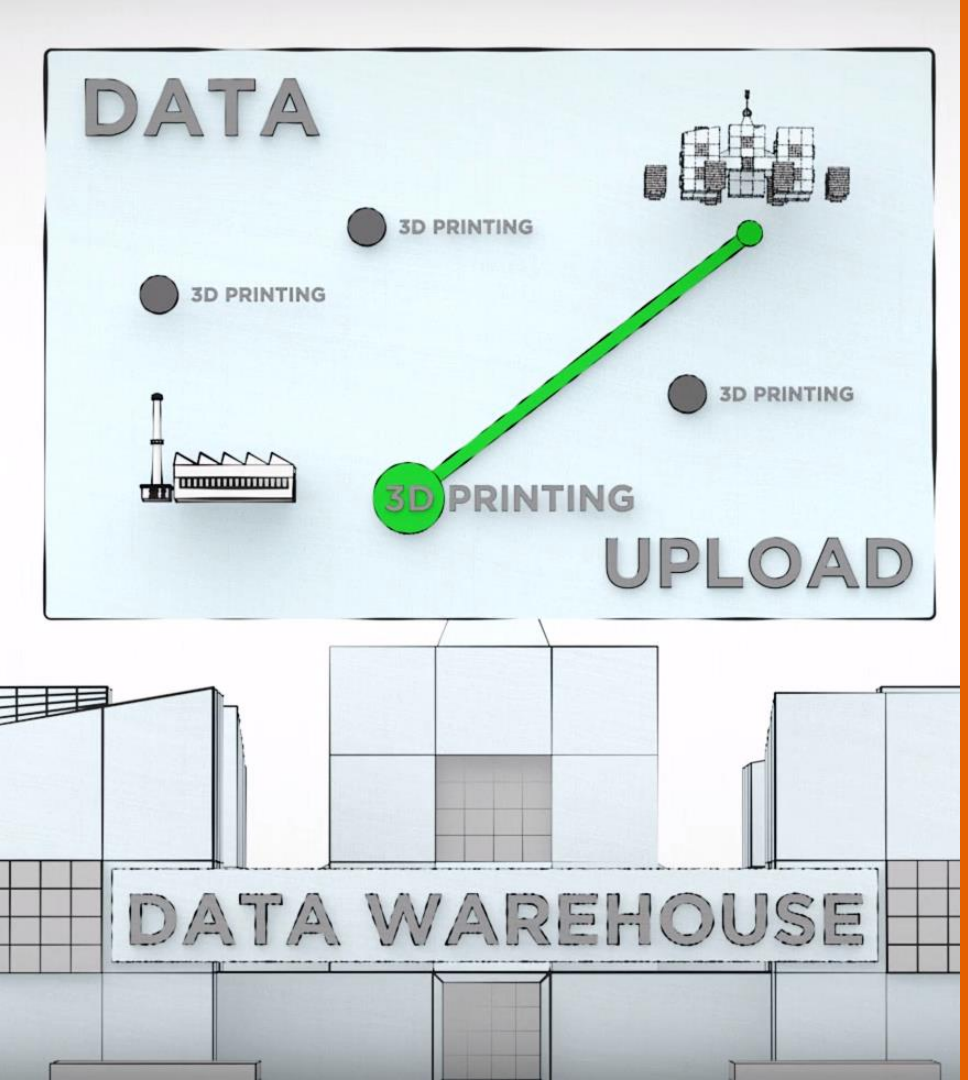
hydraulics

75 % weight reduction
1/2 size dimension

VTT – beyond the obvious

design outside the box





DIVA – digital spare parts

Identifying 3D-printable spare parts: case

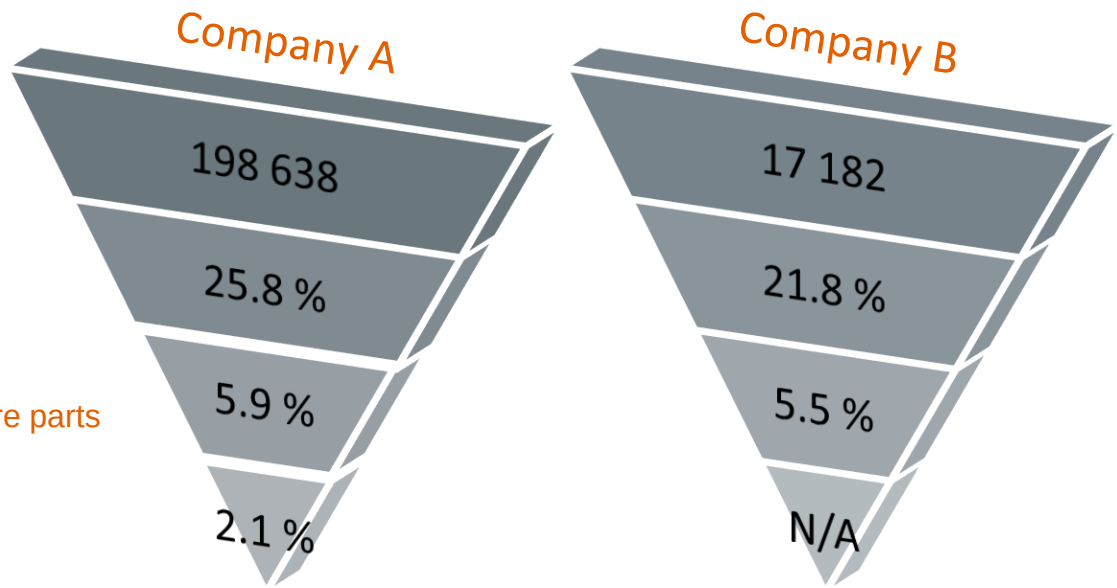
Top-down approach
Which of these parts can be printed?

Step 1: Scope and selection criteria determination

Step 2: Technologically possible spare parts

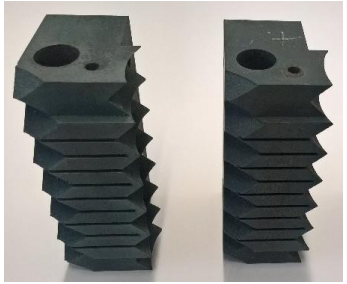
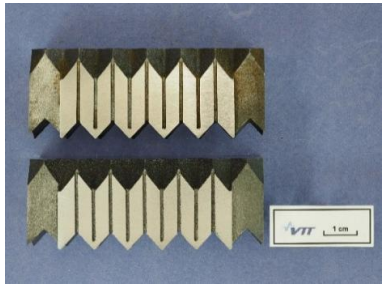
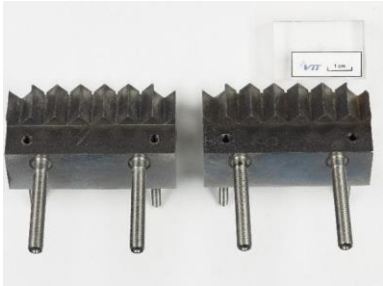
Step 3: Technologically feasible spare parts

Step 4: Technologically and economically feasible spare parts

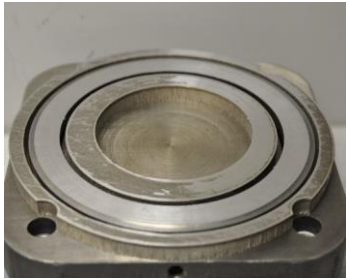


Digital spare parts – Demonstrations

1:1 replacement part: heat plate

Repairable spare part: valve seat ring




VTT – beyond the obvious

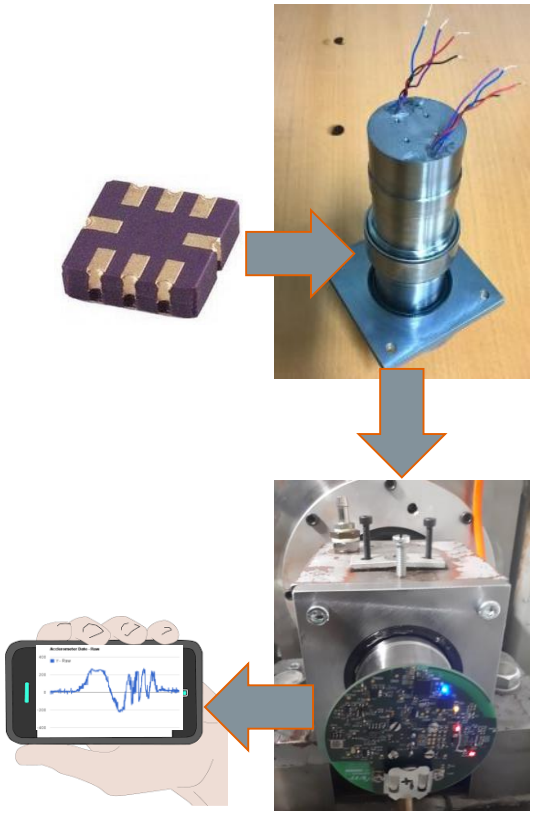
from cloud to user: digital spare parts

Smart shaft

Smart shaft informs about using condition

Successful Proof-of-concept of 3D printed smart shaft, which has acceleration sensor embedded inside the structure.

- Sensor and wiring embedded in 3D printed component during the manufacturing
- Wireless data transfer from the component to cloud
- Approach can be utilized in different components - sensors (e.g. thermocouples, Acoustic Emission sensor)
- Potential benefits:
  - More accurate in situ measurements
  - Sensing solution well shielded against harsh environment
  - Applications e.g in Condition Based Monitoring, tracking, digital ID, in various industrial domains




Smart shaft:
Embedded sensors inside AISI 316L component for improved condition based monitoring.
VTT

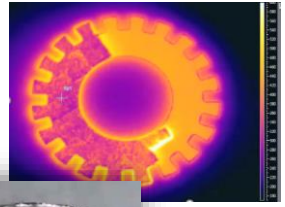
VTT – beyond the obvious

embedding intelligence to machinery

Production services

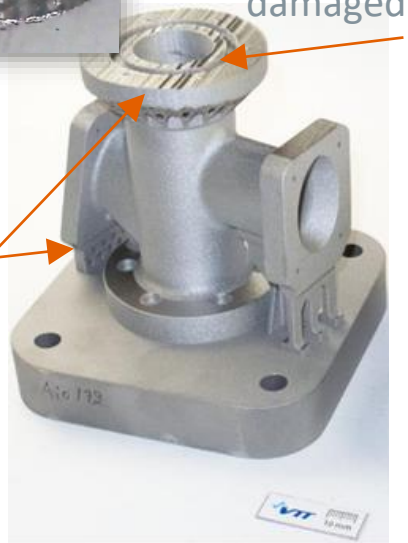
VTT Pipe

Mitigation of thermal distortions

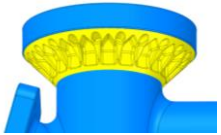


Distortions due to damaged recoater

Dross



Print ID 172



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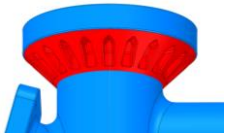
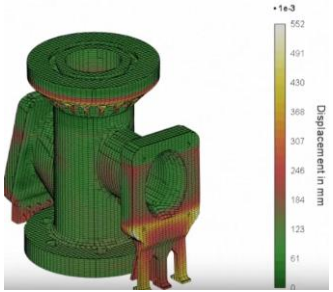
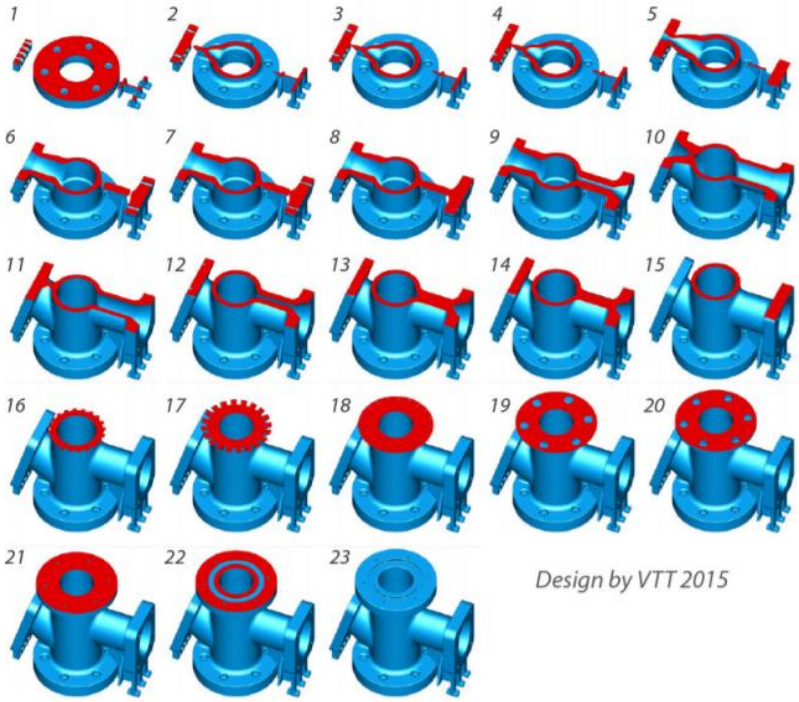


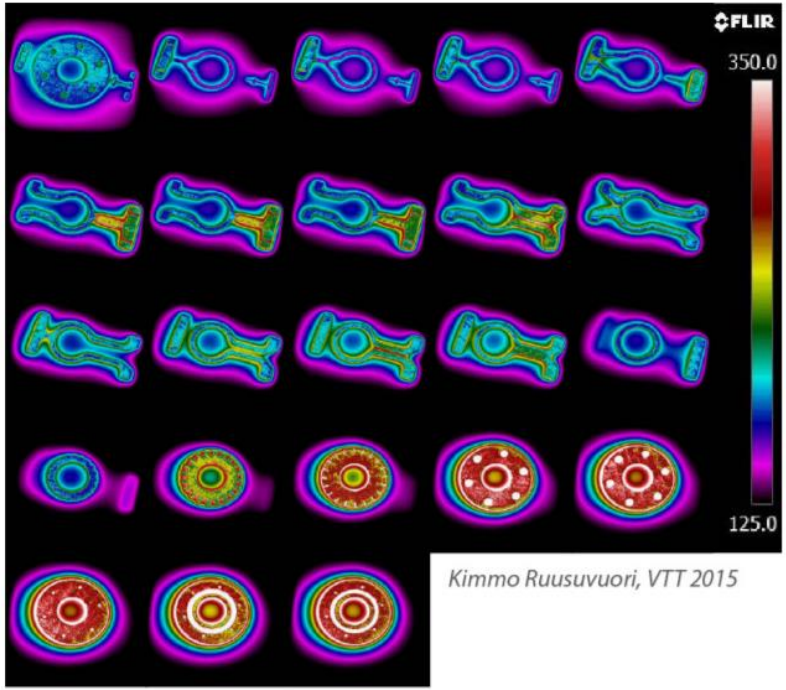


Successful print – effective thermal conduction at collar support

Process monitoring: thermal imaging



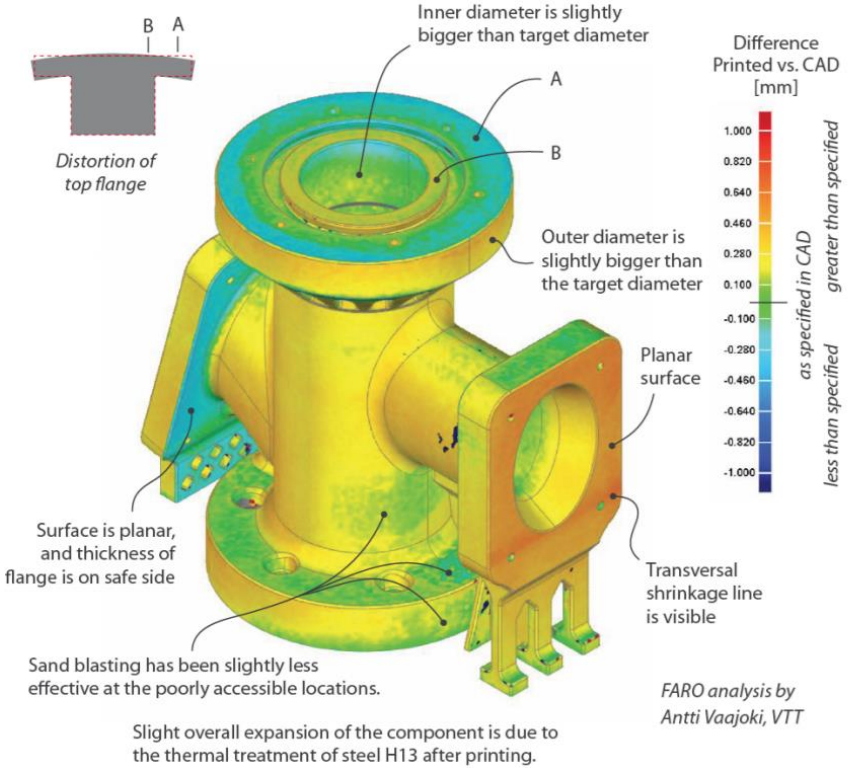
a) Studied cross-sections in CAD model.



b) The monitored temperature distributions at the end of melting of the layers.

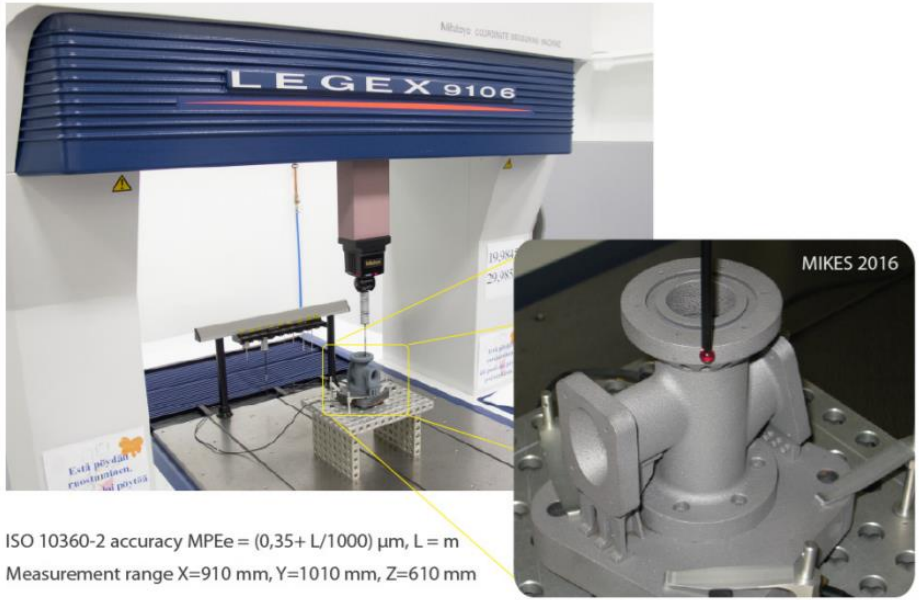
Geometrical accuracy

No component level distortion, all deviations are covered in machining allowances.



FARO analysis by Antti Vaajoki, VTT

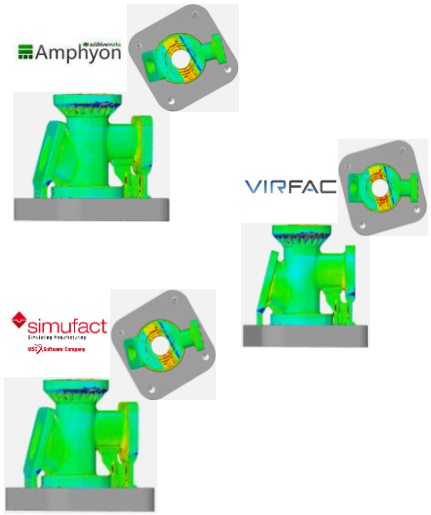
Slight overall expansion of the component is due to the thermal treatment of steel H13 after printing.

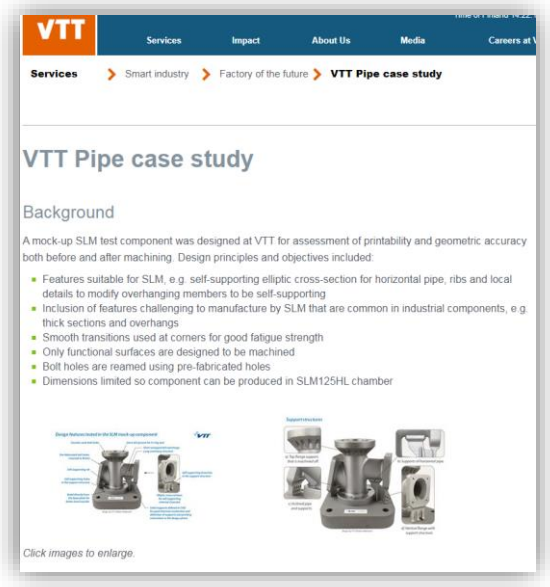


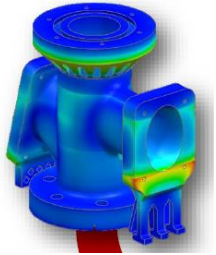
ISO 10360-2 accuracy MPEe = (0,35+ L/1000) µm, L = m

Measurement range X=910 mm, Y=1010 mm, Z=610 mm

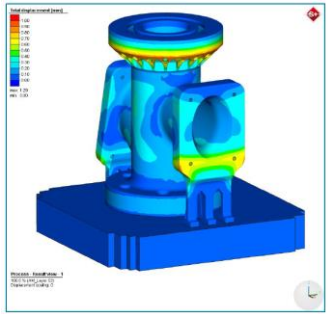
VTT → Knowledge sharing → Impact







SIEMENS
Ingenuity for life



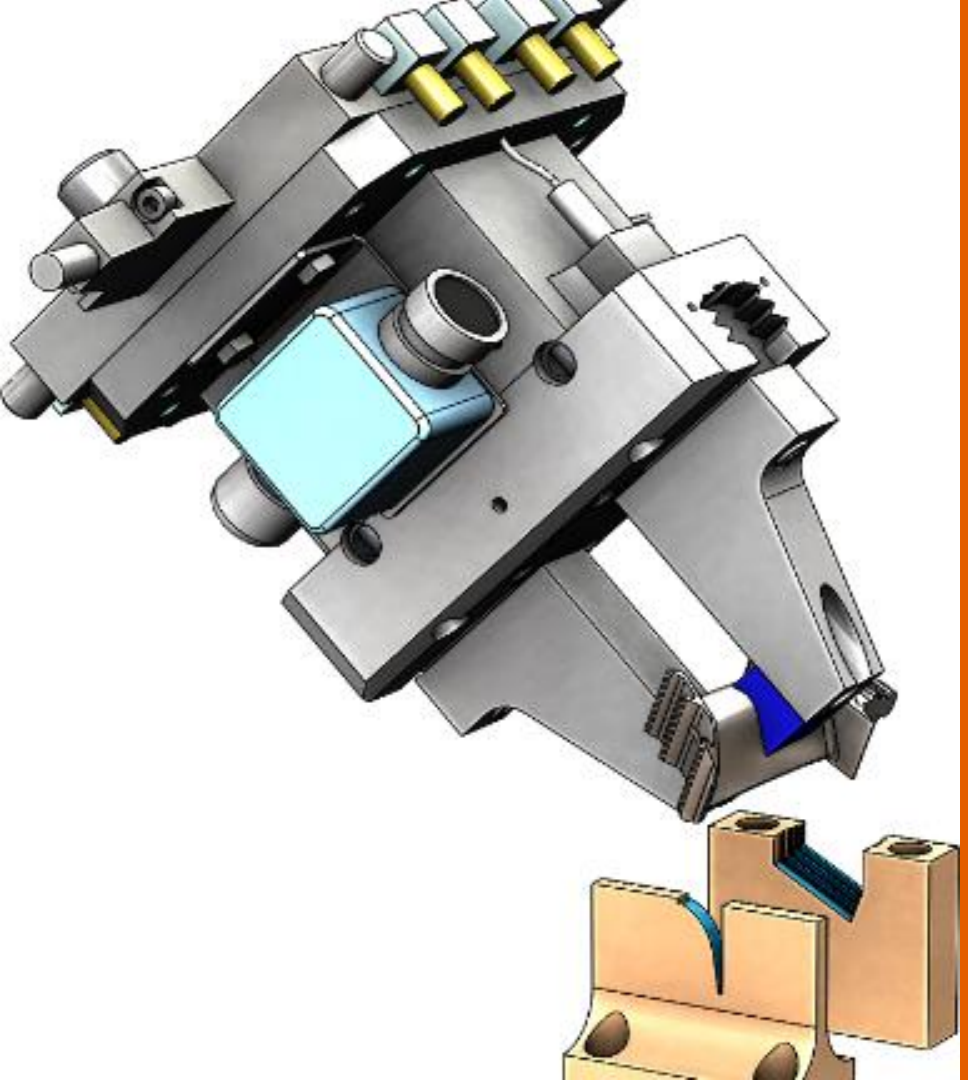
simufact
Simulating Manufacturing
MSC Software Company

Presentations in:
NAFEMS Nordic Seminar: Exploring the design freedom of additive manufacturing through simulation. 10-11.12.2018, Helsinki

https://www.vttresearch.com/vtt-pipe-case-study

VTT – beyond the obvious

VTT Pipe – open source AM test component

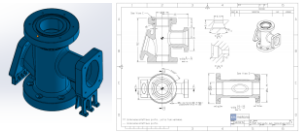


Automating post-processing for AM

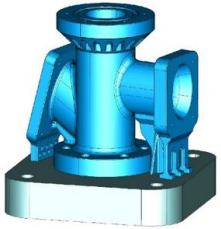
Digital manufacturing chain (MBD)

3D MBD CAD model

vs.

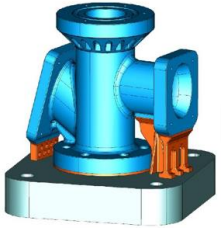


3D CAD model
2D manuf. drawing



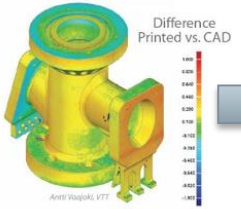
Print

Automatic toolpath generation



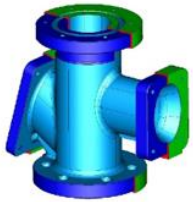
(Heat treatment)
Remove from platform
(Remove supports)

Manual



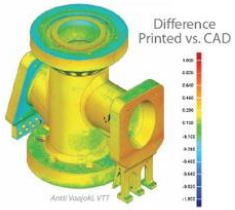
Inspect

Manual
FARO configuration (fast)



Machining

Manual
CNC programming



Final inspect

Manual
CMM programming

Post-processing time and cost can be more than printing cost
Can we automate some of the post-processing setup with MBD?


FER-1022231
SLM-90-060-001
SLM Solutions

Machining (CNC)

- MBD in machining strategy generation
  - Can aid in the creation of the tooling paths
  - All the dimensioning included in the model
  - If a certain dimensioning is missing this can be checked directly from the model. Efficiency e.g. in comparison to traditional 2D paper drawings

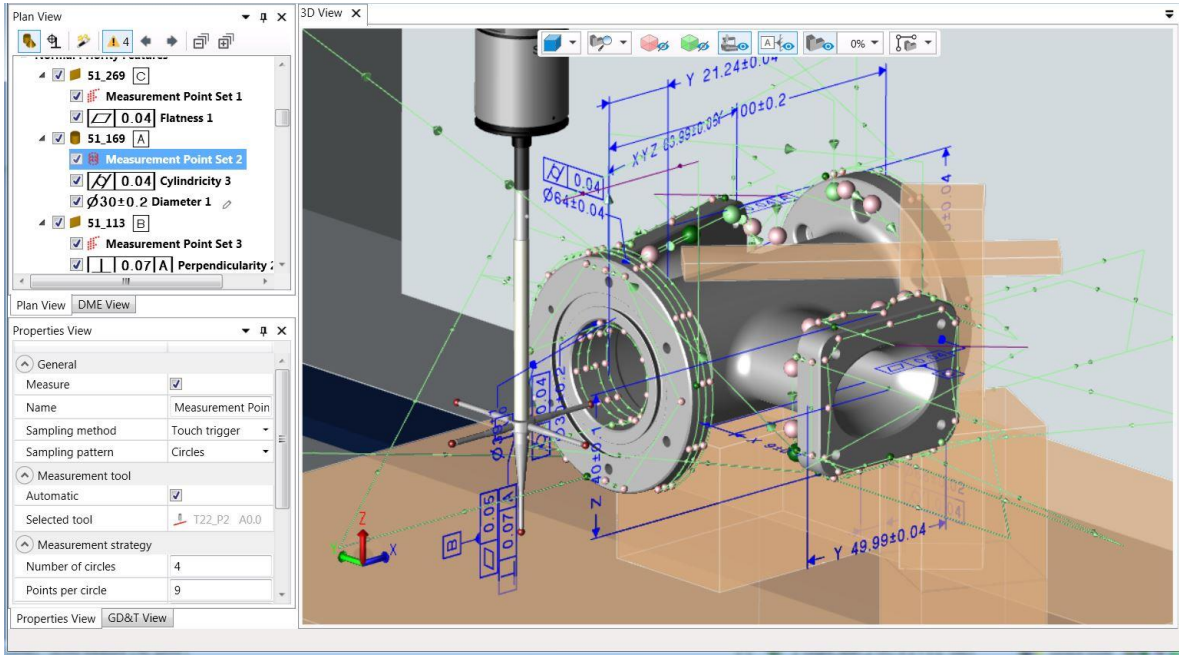
- Tested Mastercam 2018-> reads MBD annotations (step 242)
  - Still just feature based machining

- Solidworks CAM 2018 (no license yet)
  - “Tolerance based machining from MBD tolerance and surface finish information”

Final inspection (CMM)

- CMM Mitutoyo Legex
- Manual programming 1-2 days
- Using Micat Planner software to automatically create toolpath from MBD annotations
- Work reduced by 70 % from days to hours

- At this moment works only for few CAD formats
- Automatically generated CMM script is more difficult to edit afterwards than traditional recorded (teach mode) script



VTT – beyond the obvious

automated post-processing for AM

Material services

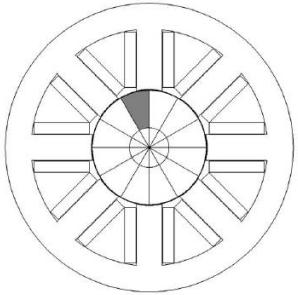
Additive manufacturing of soft magnetic materials

Topology optimization of switched reluctance machines

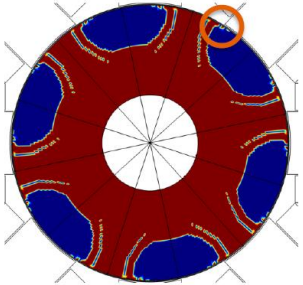
- Globally Convergent Method of Moving Asymptotes (GCMMA) optimization algorithm on COMSOL Multiphysics
- TO objective: minimize torque ripple by optimizing torque profile
- The target value for the torque, 0.16 Nm, was achieved quite well, except for the last rotor angle, when the stator and rotor teeth are aligned.

$$\text{minimize } f(\psi) = \sum_{j=1}^{n} \left(T_j - T_t\right)^2$$

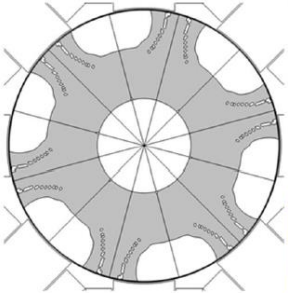
Design space



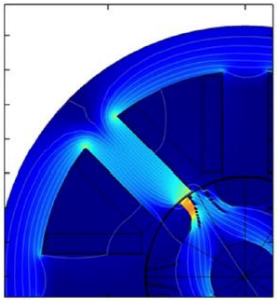
TO result

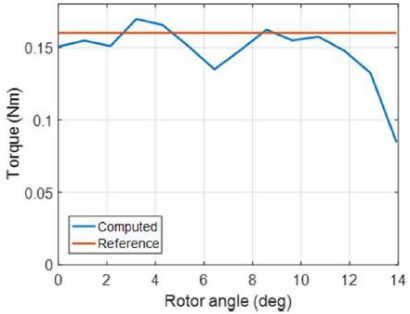


Clean result



Validate

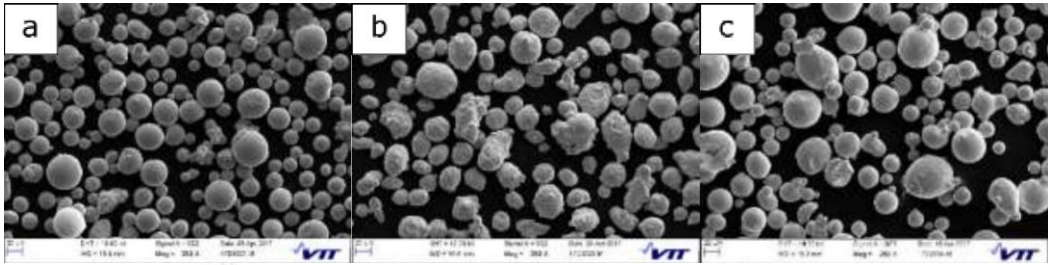


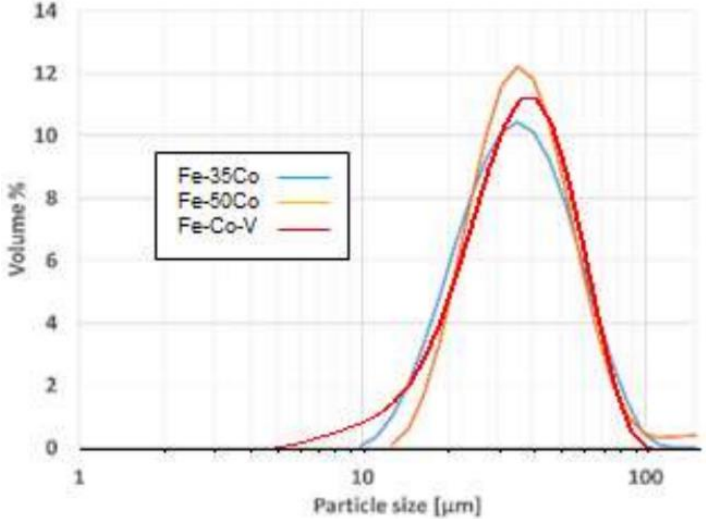


Topology Optimization of 3d Printed Switched Reluctance MotorA. Manninen, J. Keränen, J. Pippuri-Mäkeläinen, S. Metsä Kortelainen, T. Riipinen, T. Lindroos. NAFEMS Nordic Seminar Exploring the design freedom of additive manufacturing through simulation. Helsinki 10-11.12.2019

Powder preparation

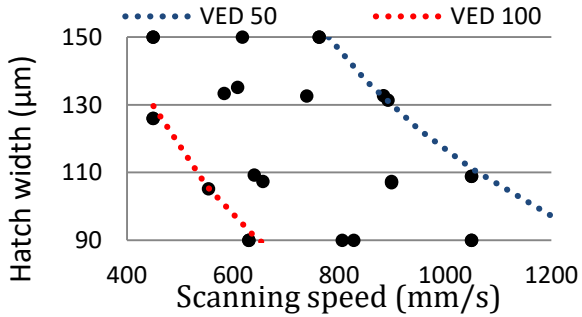
- Fe-Co alloys were gas atomized, sieved, air classified and the resulting powder characterized to determine suitability for SLM (flowability, size, shape, packing)

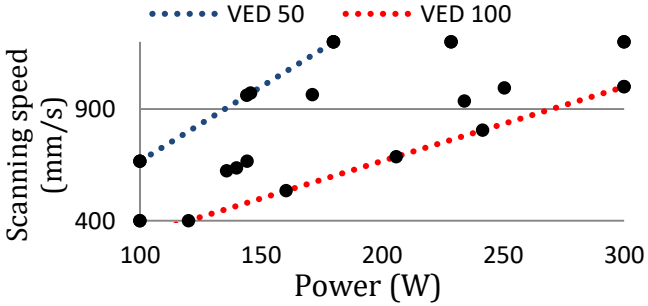




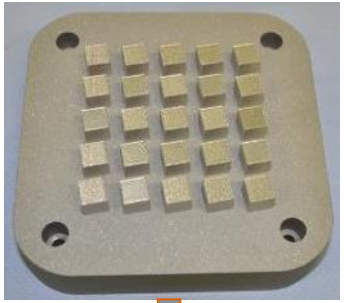
Printing parameter optimization

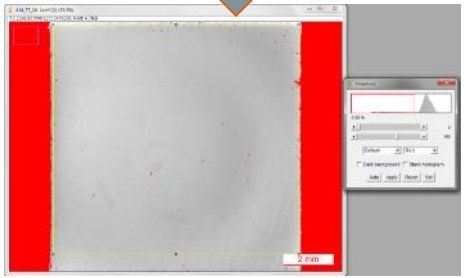
Creating the experimental designs Using D-optimal design of experiments



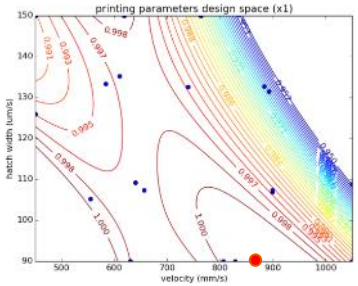


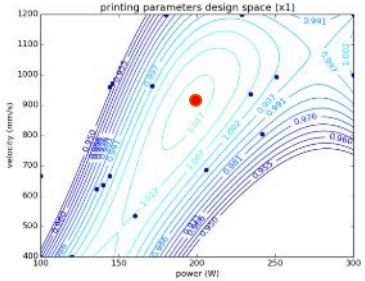
Printing samples and measuring density using image analysis





Fitting a numerical model and calculating the optimal parameters



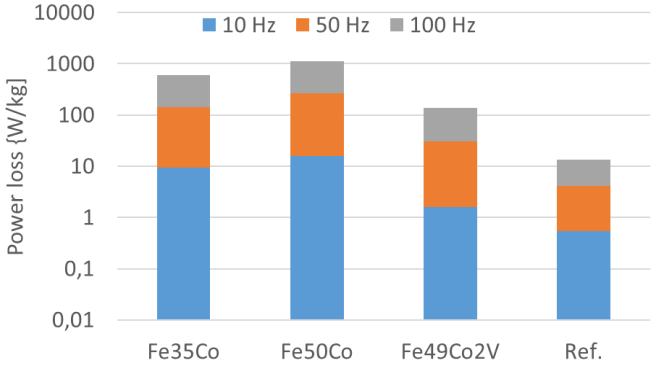


Printing of test specimens

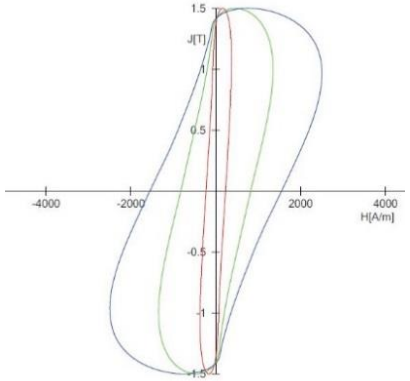
- Test parts were produced for magnetic and mechanical testing

Magnetic properties

- Good magnetic properties Br, Hc and µmax reached.
- Eddy current losses still high, next development steps to reduce the losses



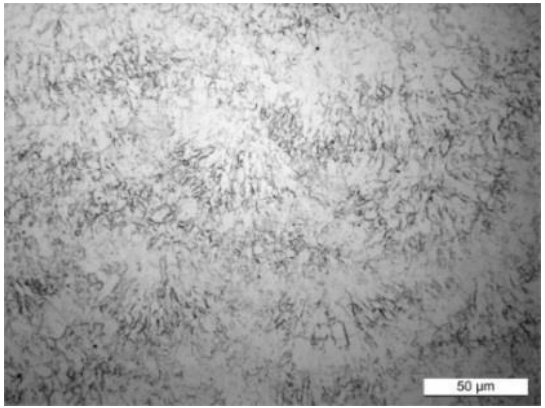
	Sample type	Heat treatment	Br (T)	HcB (A/m)	HcJ (A/m)	µmax (-)	H(µmax) (A/m)	Hmax (kA/m)	Jmax (T)	Bmax (T)
Fe-Co-V	Bar	As-built	0.90	1344	1345	307	1930	55	2.10	2.17
	Ring		0.88	1287	1288	322	1754	9	1.56	1.57
	Bar	HT1	1.59	73	73	9156	72	56	2.22	2.29
	Ring		1.56	493	493	1922	125	9	2.16	2.18
	Bar	HT2	1.51	52	52	17000	47	56	2.21	2.28
	Ring		1.31	47	47	13000	60	9	2.22	2.23
	Commercial bar*	HT1	0.51	59	59	4300	272	57	2.16	2.24
	Commercial ring*		1.26	40	40	12000	53	10	2.22	2.23



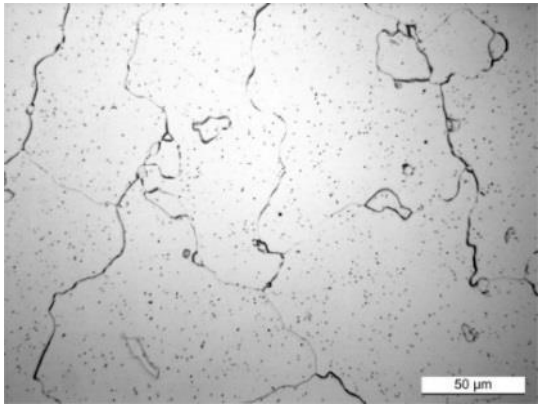
Microstructure & mechanical properties

- Mechanical properties of printed Fe-Co-V samples compared well with standard FeCo-alloy

As-built



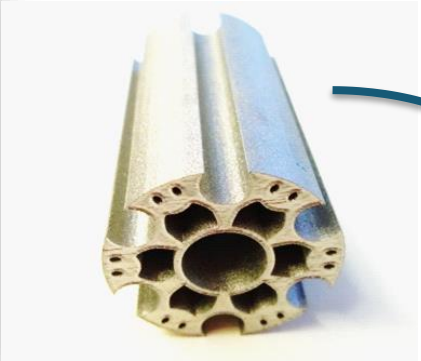
Heat-treated (HT2)

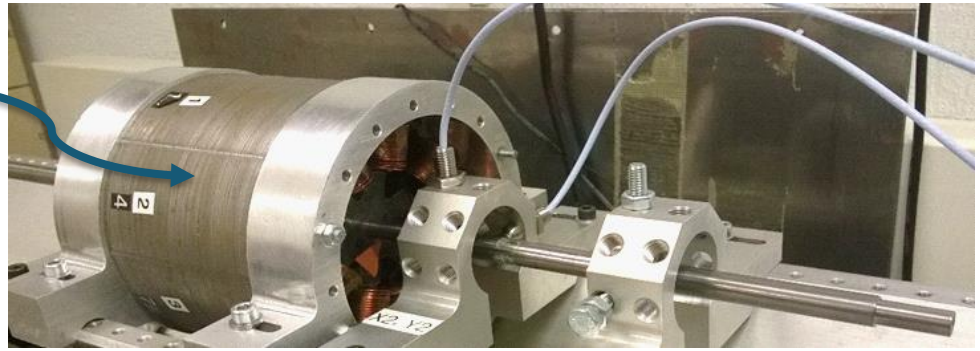


Material	Build orientation	Condition	Ry0.2 (MPa)	Rm (MPa)	A (%)	E (GPa)
Fe-Co-V	Horizontal	As-built	839	968	4	230
		HT1	303	363	3	204
		HT2	266	306	3	210
ASTM A801-09 alloy 1		Heat treated*	250	350	3	215

Component manufacturing & testing

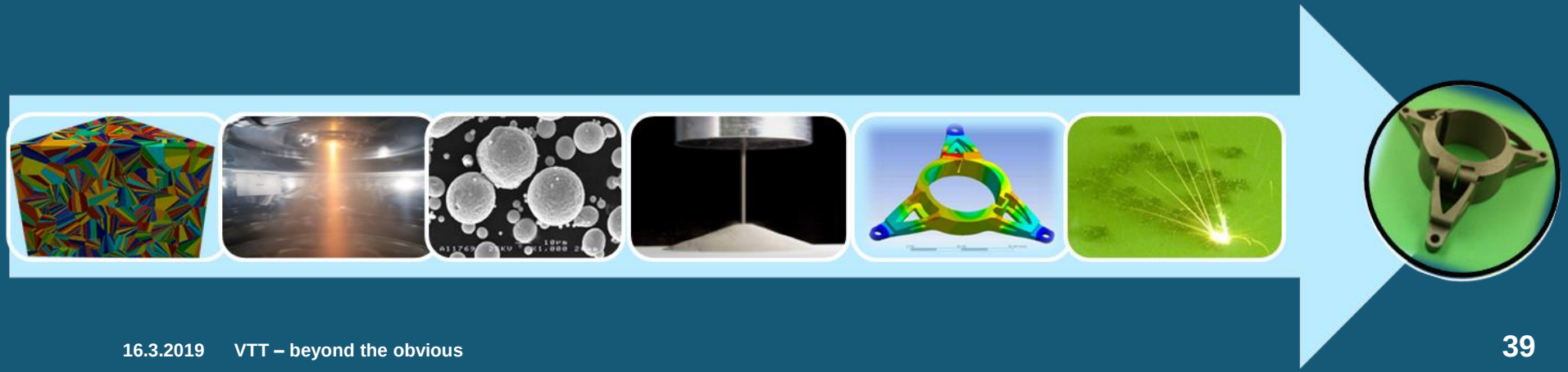
- Optimized rotor for electrical machine was manufactured
- The results that we have obtained are promising, i.e. the key characteristics mainly fulfil the requirements of commercial electrical machines





VTT – beyond the obvious

from powder to product



AMable Open Call
Your Opportunity

1 Do you have an innovative idea for a functional product that needs AM to become alive? You can tell & sell its story publicly but you cannot achieve the implementation yourself?

2 You can get support from European Additive Manufacturing Competence Centers – teamed up in AMable – through services for design, testing, simulation, scale up, etc.

3 You can get funding for your development activities if you are an SME in the supplier role, eligible under Horizon2020 rules and if there is a SME or mid-cap in the user role.

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Thank you!

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