Additive Manufacturing for Nuclear Power Plant Applications

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VATTENFALL

Introduction Ringhals

Ringhals 1 (R1)
BWR, ASEA ATOM
Commercial operation 1976
Shut down 2020

Ringhals 2 (R2)
PWR, Westinghouse
Commercial operation 1975
Shut down 2019

Ringhals 3 (R3)
PWR, Westinghouse
Commercial operation 1981
Planned service life 60 years
Investigation of 80 years

Ringhals 4 (R4)
PWR, Westinghouse
Commercial operation 1983
Planned service life 60 years
Investigation of 80 years

Connecting additive manufacturing with future challenges

Opportunities

- Strengthen security of supply
- Reduce costs and time
- Support plant life extension (80+)
- Support new build programs
- Mitigate geopolitical risks

Application Areas

- Obsolescence
- Replacements of components
- Improve robustness
- Repair/renovation

Sustainability

- Climate Change
  - Regulatory Requirements
  - VF Net Zero 2040
  - Customers Expectations
- Minimal material consumption
  - Less Waste
  - Less Energy Consumption
- Reduce Transports
  - From Centralized to Localized Manufacturing

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AM for NPP applications

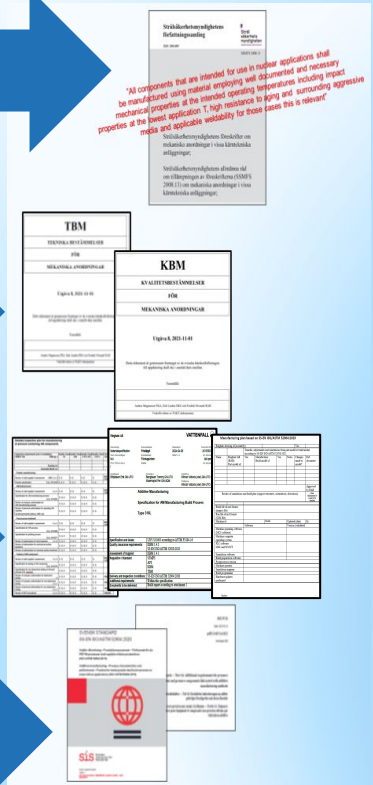
AM products in the NPP

Regulatory aspects

NPP Technical Requirements

NPP Qualification (QA/QC)

Standardization (ISO/ASTM)



Competence exists, e.g.:
EPRI
EU
IAEA
…
However, we conclude that we need in-house competence.

Need for R&D

Ringhals Strategy - Additive Manufacturing

Application Center for Additive Manufacturing

Capabilities

Pre-AM
- ✓ Powder characterization
- ✓ Advanced characterization

DFAM
- ✓ Topology Optimization
- ✓ Process Simulation

AM Printing
- ✓ Metal: LB-PBF, DED, MBJ
- ✓ Polymer: FDM (large scale), SLA, SLS
- ✓ Ceramic: SLA

Post-AM
- ✓ Subtractive processes
- ✓ Heat treatment
- ✓ Surface modification

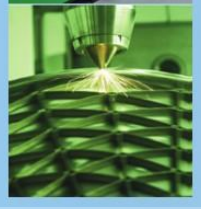
Quality Control
- ✓ 3D-scanning
- ✓ Digital Analytics
- ✓ CT-Scanning

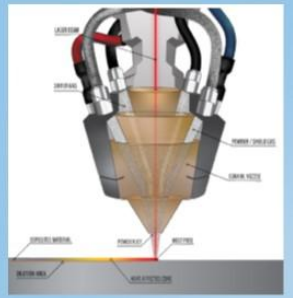
Partners

Alfa Laval · Quintus Technologies · materialise · Sandvik Coromant · Volvo · Hexagon · Chalmers University of Technology · Ericsson · DNAam · Höganäs · AddUp · Siemens Energy · Vattenfall · Modul-System · RISE · RENA · Digital Metal · Volvo · Nikon · Adaxis · SSAB

POWDER BED FUSION (PBF-LB)

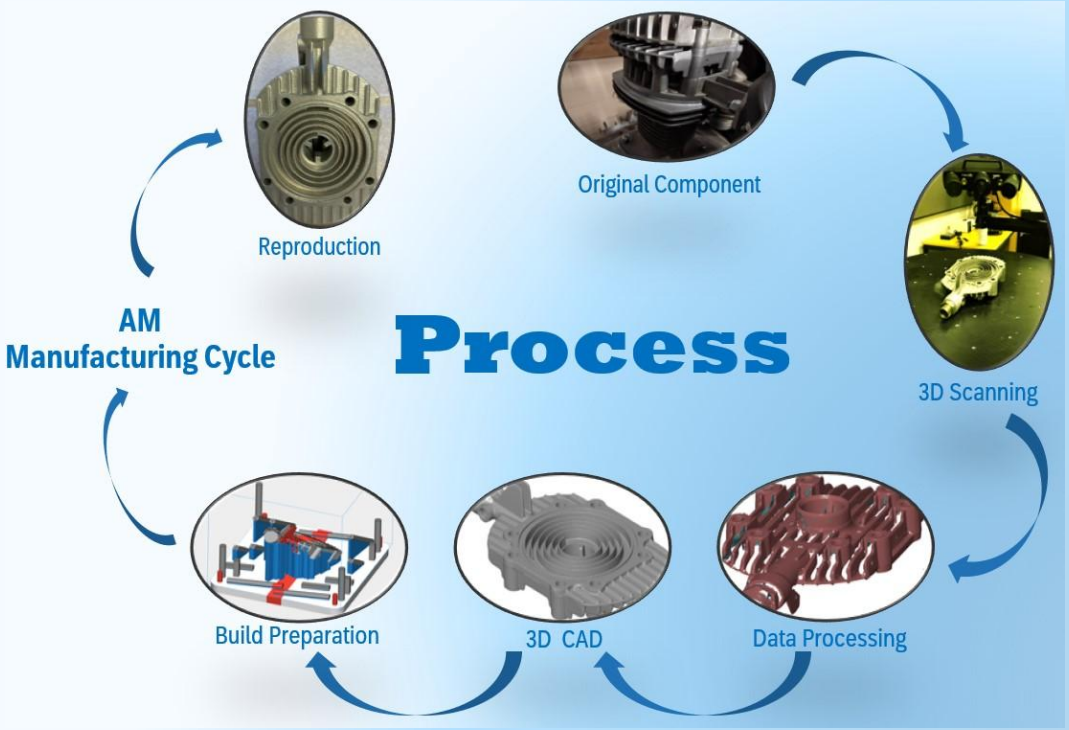
DIRECTED ENERGY DEPOSITION (DED)





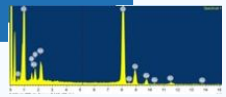
Example of one possible route

Digitization - Reversed Engineering - AM

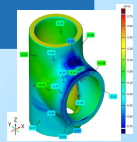


Strategy

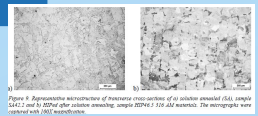
Chemical Composition



Build Tolerances

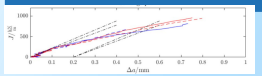


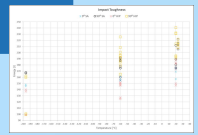
Grain Size & Component Microstructures



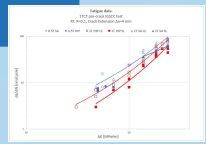
Mechanical Properties

Toughness properties

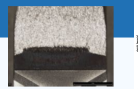


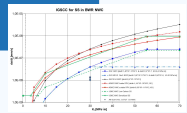


Fatigue



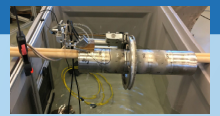
Corrosion

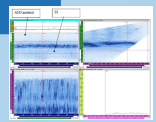




Weldability

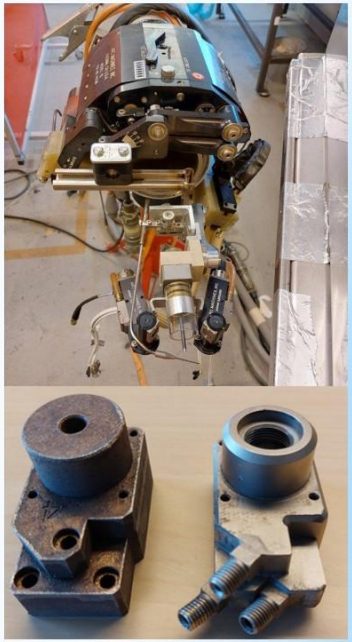
NDE



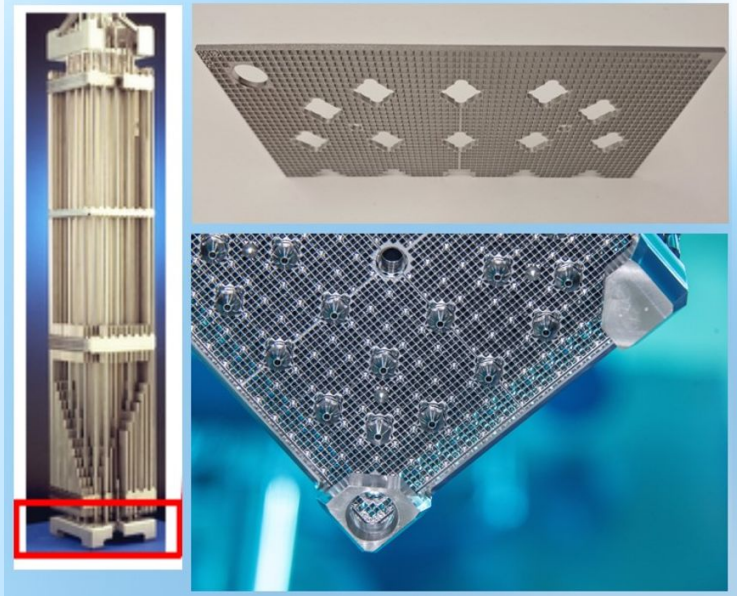


Applications

Welding head



Anti-Debris Filter - GAIA (FRAMATOME):
½ ADF in 4 Fuel Assemblies – Installation 2024 R4



Pilot project #1

Robustness

Anti-vibration support

System: 30/40-327
(Auxiliary Feeder Water)

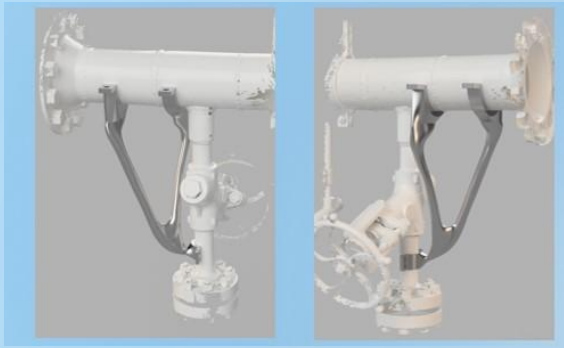
Quality Class: 4

Material: SS316L

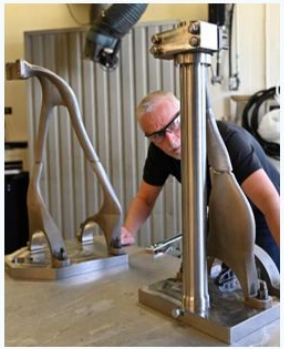
AM Method: PBF-LB

Print Start/Final: 2024

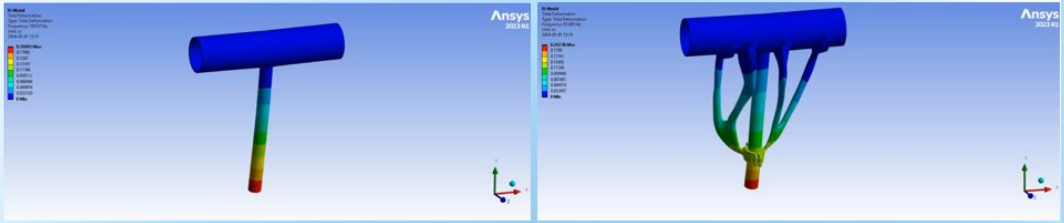
Heat Treatment: HIP-SA



Pilot project #1

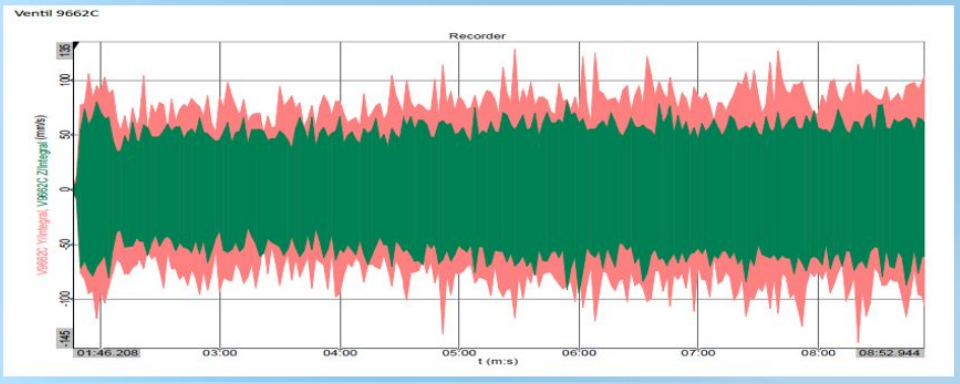


Numerical Modal Analysis: Natural frequency 20 to 96 Hz



Vibration velocity 0-Peak [mm/s]

Allowed 169 / Measured 140



Pilot project #2

Obsolescence

Diesel Engines/Compressor Cover

System: 30-652 p011

Environment: 35 Bar/50ºC

Quality Class: 4

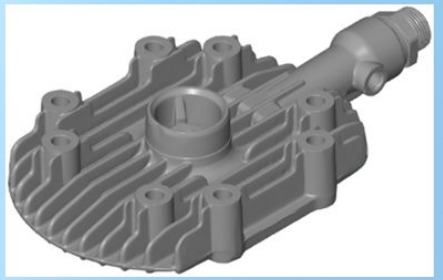
Material: Aluminum type AlSi10Mg

AM Method: PBF-LB

Print Start: 2024

Heat Treatment: HIP

Final part completion: 2024



Waiting for Harmonized Standard (PED) for Pressurized Components

Pilot project #3

Pressure Component

System: 30-337 (Blow Down System, BD)

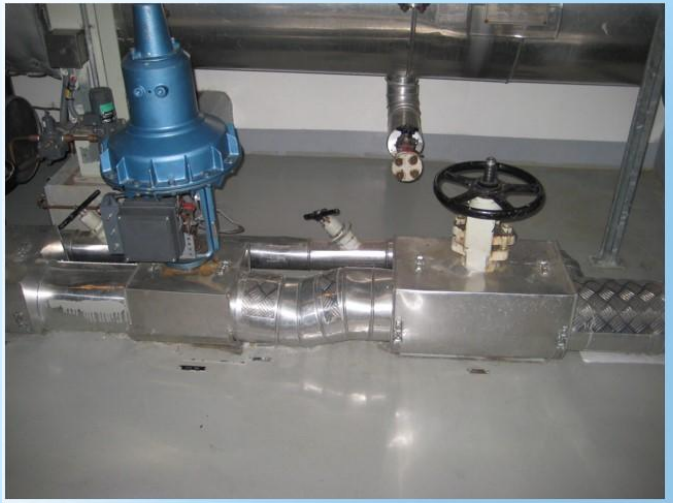
Quality Class: 4

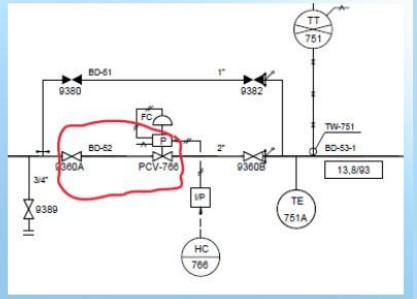
Material: SS 316L

AM Method: PBF-LB

Print start: TBD

Pipe Segment

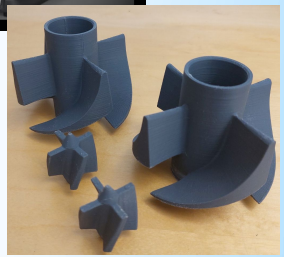




Waiting for Harmonized Standard (PED) for Pressurized Components

Polymeric materials

CREALITY - FDM 3D printer



SLS 300

Connecting additive manufacturing with future challenges

Potentials with AM

- Reduce
  - Production Loss
  - Lead Times
  - Manufacturing Costs
- In-House Manufacturing
- Reversed Engineering
- Cost effective
  - One-Piece Production
- On-Site Repair
- On-Demand Manufacturing
- Digital Warehouse
- Optimized Design (DFAM)
  - Number of Welds
  - Weight Reduction
  - Maintenance Costs
- Equivalent/Improved Structural Integrity
- Extended supply chain
- Alloying Requirements
- …

Thank you!