Taisteluvaurioituneiden metalliosien kierrätys
Recycling of battle-damaged metal scrap

Matine tutkimusseminaari 19.11.2024

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Project duration 2/2024-12/2024, total budget 94 k€

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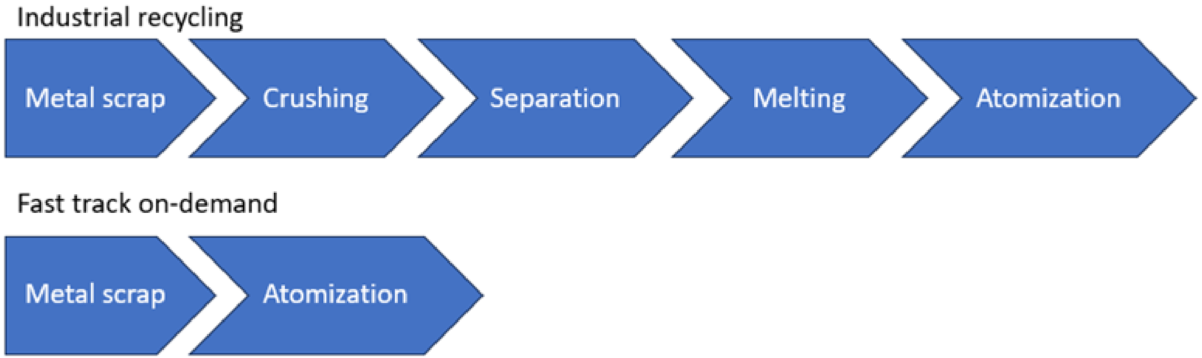
Background

- Previous conflicts have shown, that even if critical materials and spare parts are stored, longer crisis might cause scarcity of them
- During an extreme situation (e.g., military crisis), a spare part which would not necessarily fulfill all quality requirements during the normal situation, could help to keep troops and weapon systems functional
- 3D printing can help security of supply related to spare parts, but without feedstock material it is useless technology
  - Even if feedstock is available, 3D printing would not eliminate need to keep certain spare parts in stock, only to support this strategy

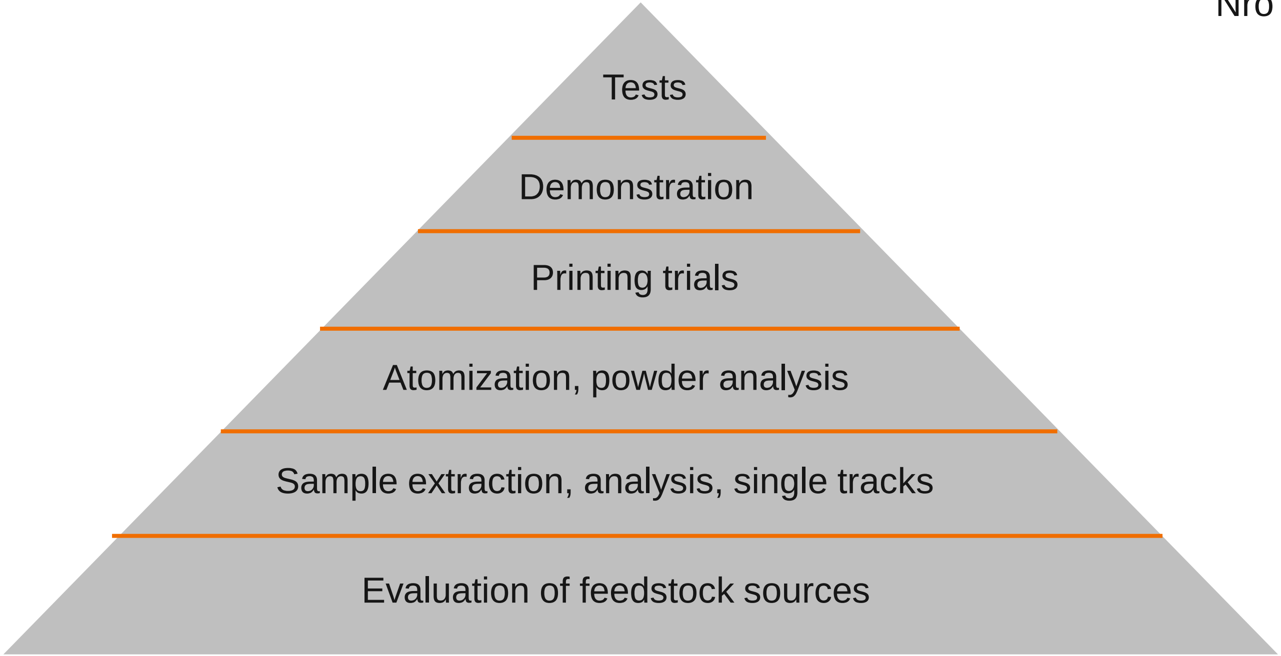
Research question

- The project aims to answer the research question of *how battle-damaged or otherwise decommissioned scrap metal can be recycled back into raw material and further manufactured from this raw material into spare parts components by 3D printing.*
- The project also wants to clarify and open the *challenges* and *bottlenecks* that may be associated with this type of operation, as well as outline the *key actors* and the *necessary infrastructure*.
- 3D printing process in focus, laser-beam powder bed fusion (PBF-LB)

Metal recycling from scrap to product



Implementation and amount of materials



Nro of materials

1

2

3

5

5-10

Materials for the study

Tools for extrusion
Inconel718 (orig.)

Rusty steel shaft
4140 steel (XRF)

Rock drilling crowns
48CrMoNi4-10 steel

Aluminum profile
Al6063 (XRF)

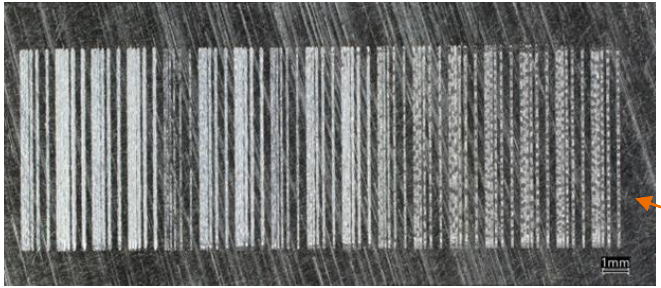
Fighter plates
Al2014-T6 (orig.)

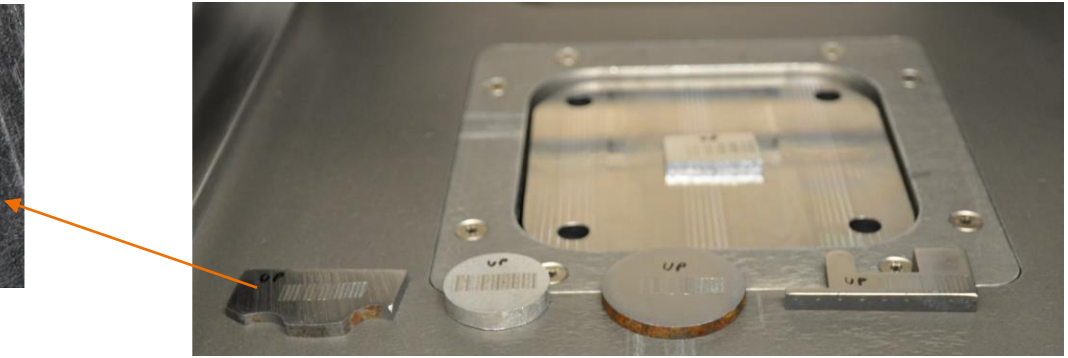
Feedstock analysis and preparation of material samples

- Scrap metals were analyzed by portable material scanner (x-ray fluorescence, XRF) in location
- We got information about the materials also related to their origin
- Various cleaning methods were tested for selected materials:
  - Paint remover
  - Shot peening
  - Angle grinder
  - Ultrasonic bath
- Some impurities still left on samples

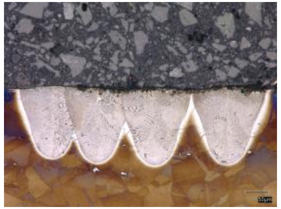
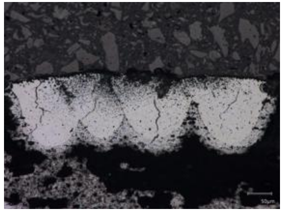
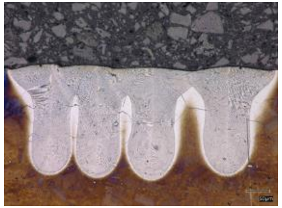
Manufacturability assessment

- Single-track laser melting trials on solid substrates of all the selected alloys
- Same experimental set applied on all alloys
- Using the laser of the SLM 125 3D printer
- To assess 3D printability before powder (faster and cheaper)
  - Cracking, other defect formation
  - Narrow down process parameter window for 3D print trials





Single-track crosscuts

	INC718	4140 steel	48CrMoNi4-10 steel	Al6063	Al2014-(T6)	
1000 mm/s, 300W, 0.30 J/mm (7)				NA		
500 mm/s, 200W, 0.40 J/mm (2)				NA		2000 mm/s, 400W, 0.20 J/mm (17)

Manufacturability

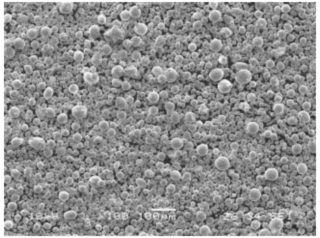
Powder manufacturing and analysis

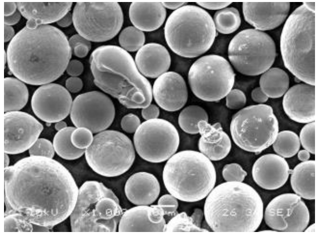
- INC718, 48CrMoNi4-10 steel and Al204-T6 were selected for atomization
- Atomization was done at VTT premises with PSI Hermiga 75/5 VI
  - Vacuum induction melting, MAX input ~5kg steel eqv. and Tmax ~1700°C
- Powder properties:
  - SEM images
  - Particle size distribution
  - Chemical composition
  - Hall flow
  - Tap density

Powder properties

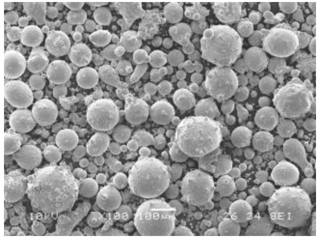
chemical composition of powders matched with the standard nominal composition

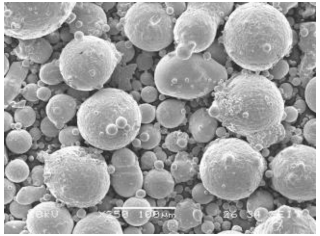
INC718



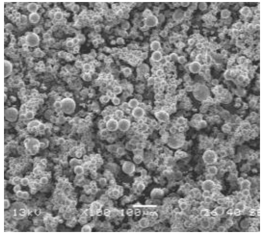


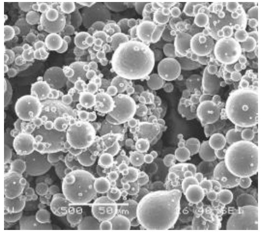
48CrMoNi4-10 steel

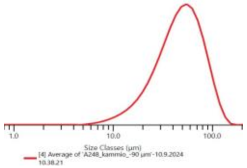




Al2014-(T6)

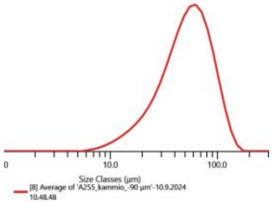






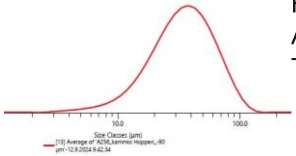
Hall flow, *no flow*.
Apparent density 4.4 kg/l
Tap density 5.4 kg/l

After 90 µm sieve
D50 48.2 µm



Hall flow: 22.8 s/50 g.
Apparent density 4.5 kg/l
Tap density 4.9 kg/l

After 90 µm sieve
D50 53 µm

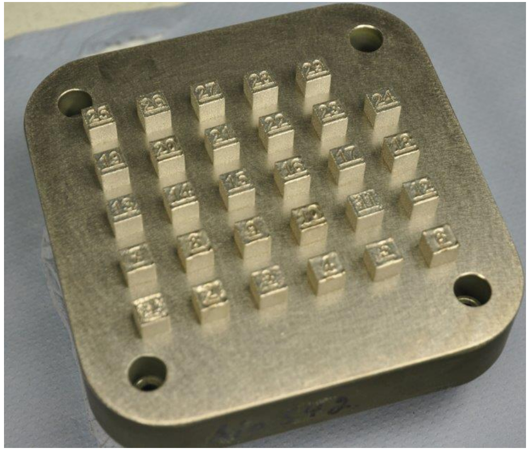


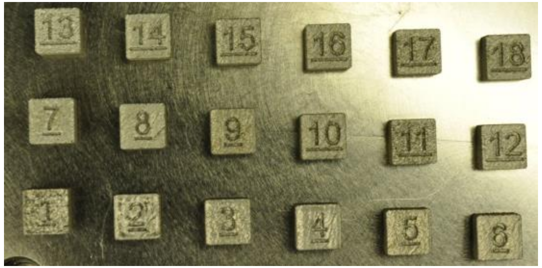
Hall flow: no flow
Apparent density - kg/l
Tap density - kg/l

After 90 µm sieve
D50 34.7 µm

DoE 3D printing

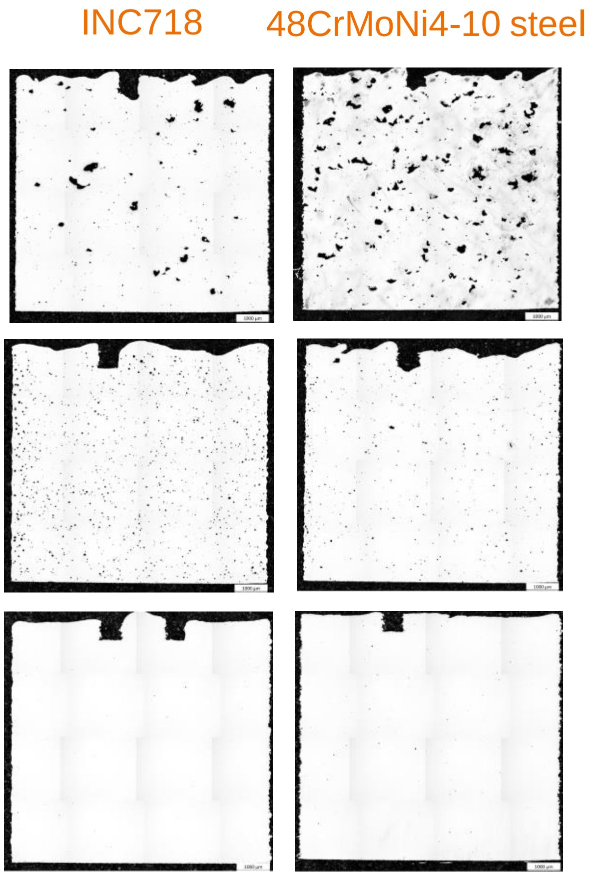
- Printing trials were carried out with VTT SLM125HL PBF-LB machine
- INC718 and 48CrMoNi4-10 steel were selected for the printing trials
- Design of experiments (DoE) set was done for both materials to fine correct main parameters
- During the trial, we followed the process with thermal camera and melt pool monitoring





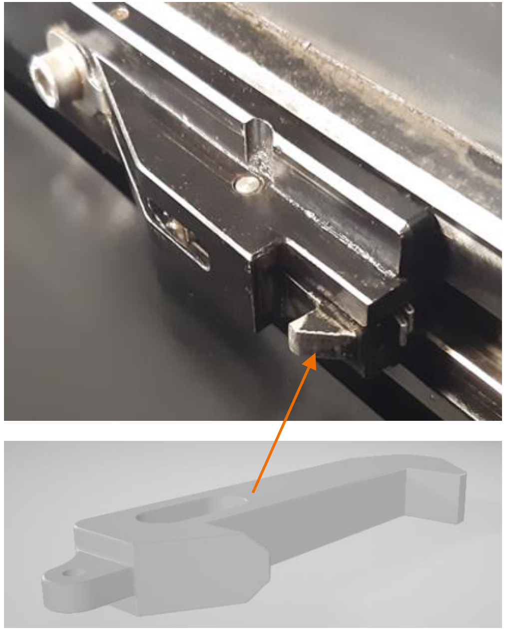
DoE 3D printing results

- Evaluation of build quality:
  - amount (and type) of porosity
  - surface appearance
  - process stability (spattering)
  - dimensional stability indication
- If several equally good samples, we considered productivity
- Good parameter set was found for both materials
  - parameters for H13 tool steel were inside the suitable operation window of 48CrMoNi4-10 steel



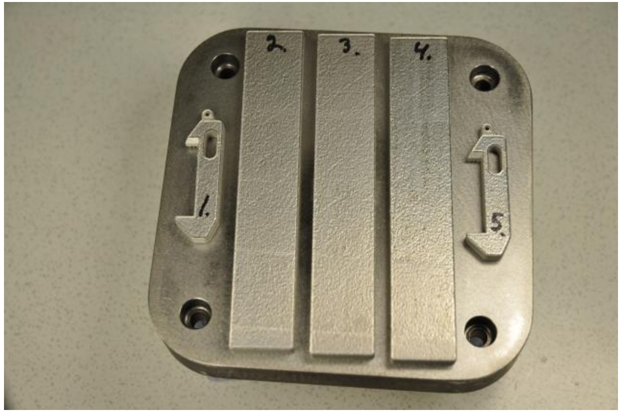
Demonstration and testing

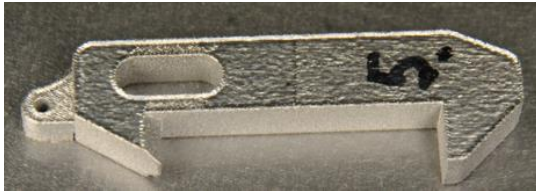
- Demonstrator and test samples manufactured from 48CrMoNi4-10 steel, as it is novel AM material, using H13 parameters
- A small spare part selected to demonstrate the concept
  - Part of firearm loading unit
- Additionally, three flat tensile test bar blanks were printed in the same build
- Vickers hardness (VH10) was measured from selected DoE samples



Demonstrator

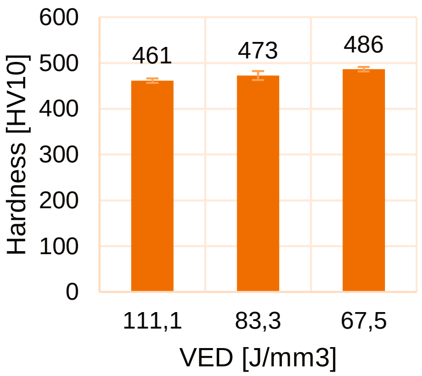
- Demonstrator build was carried out successfully
- Parts were detached from the platform by electrical discharge machining (EDM)
- No heat treatments (no stress relief)
- Tensile test bars machined from the blanks

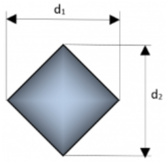




Test results

- High as-built hardness, roughly comparable to heat treated bulk steel
  - Lower heat input produced slightly higher hardness
- Tensile test results not yet available
  - Based on other results, we expect rather high tensile strength
  - Results expected within two weeks





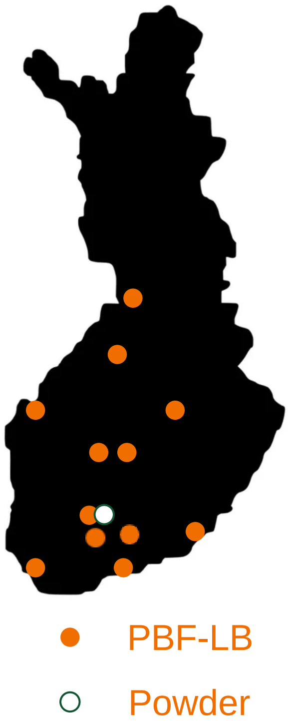
https://steelnavigator.ovako.com/steel-grades/48crmoni4-10/

Conclusions

- Technical point of view, the proposed concept seems to be feasible – up-scaling would require further development and new infrastructure
- Fast screening procedures (single tracks, DoE) provides good insight of material 3D printability

Infrastructure:

- Quite good overall availability of PBF-LB machines, in service suppliers and universities/RTOs
  - located mainly in south and west Finland
  - some machines dedicated to certain material groups
  - In addition to 3D printers, requires also some other infra (heat treatment, machining)
- Only one pilot powder manufacturing unit, too small batch size to meet the needs of production during the exceptional situation



Thank you!

One stop shop for metal AM RDI