



IN-SITU HEAT TREATMENT TO IMPROVE THE METALLURGY OF HOT WORK TOOL STEEL FABRICATED BY LASER ADDITIVE MANUFACTURING

5th Postgraduate Research Symposium on Ferrous Metallurgy 2022

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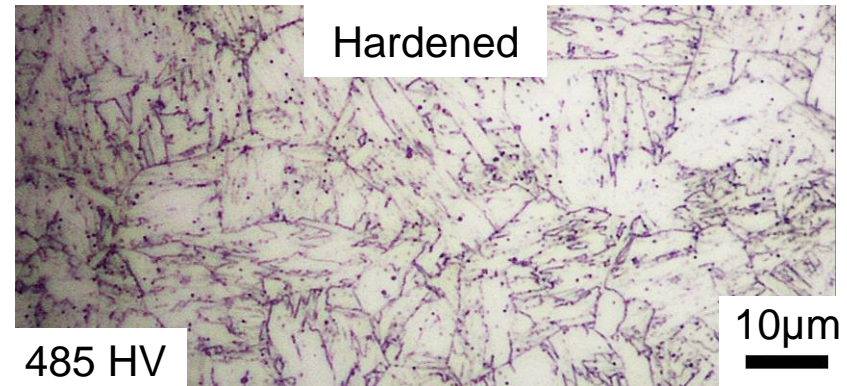
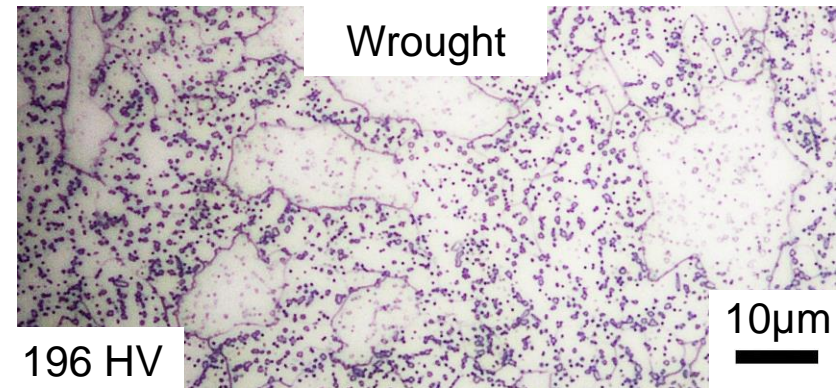
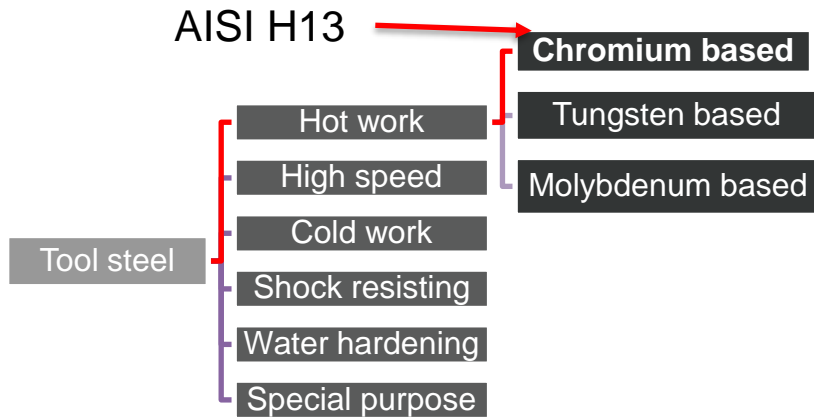
² Renishaw Plc, Gloucestershire, UK

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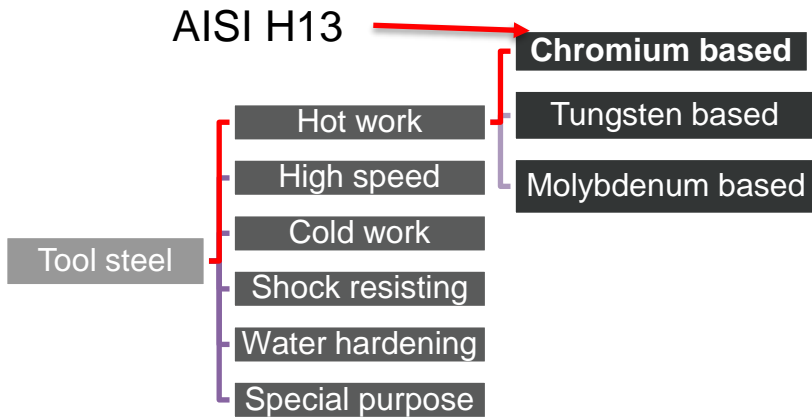
LinkedIn: <https://uk.linkedin.com/in/anna-tholen-172700b1>

1. Introduction to the problem
2. Research objectives and experimental methods
3. Results: mechanical properties
4. Results: microstructural evolution
5. Incorporating in-situ heat treatments into an industrial process
6. Conclusions

The Problem



The Problem



Laser powder bed fusion (LPBF) additive manufacturing (AM)

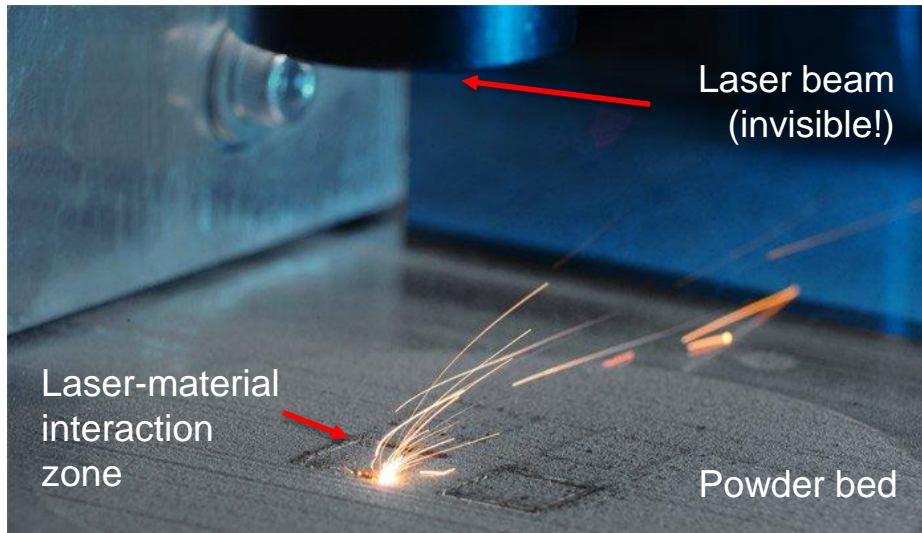
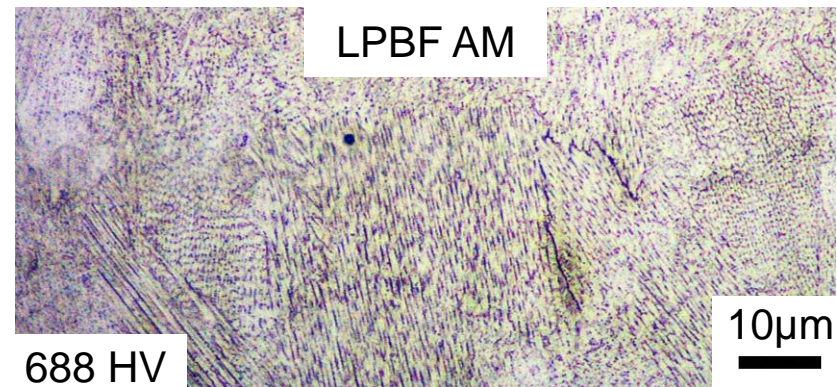
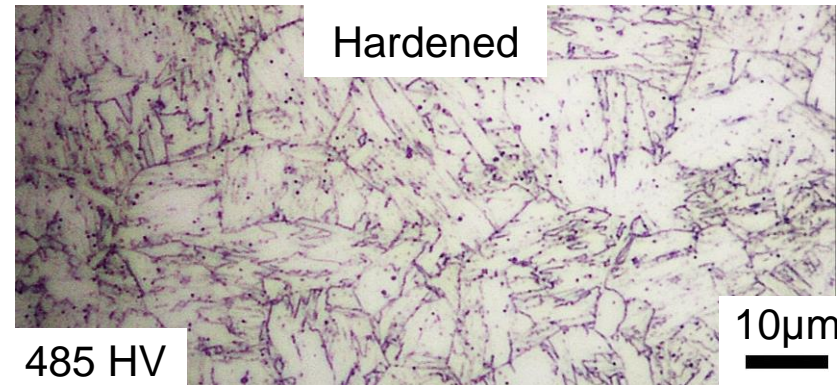
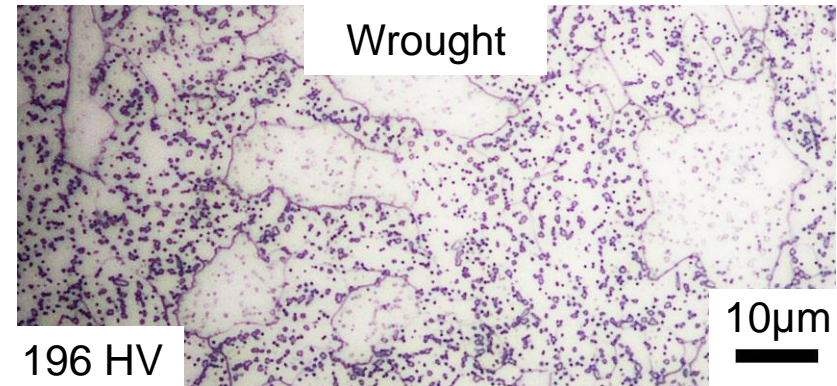


Image sourced from <https://www.3dnatives.com/en/direct-metal-laser-sintering100420174-2/>



The Problem

High misorientation

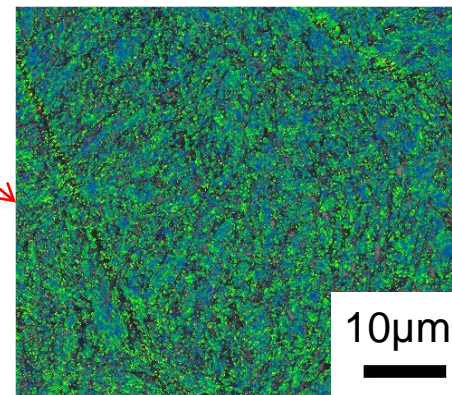
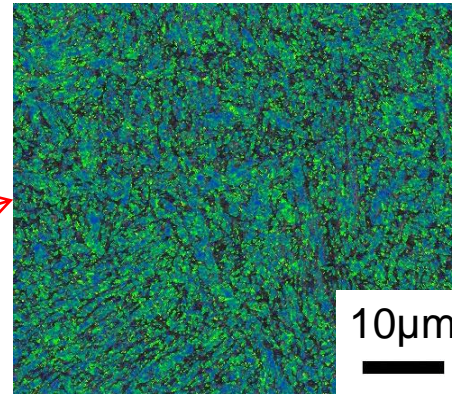
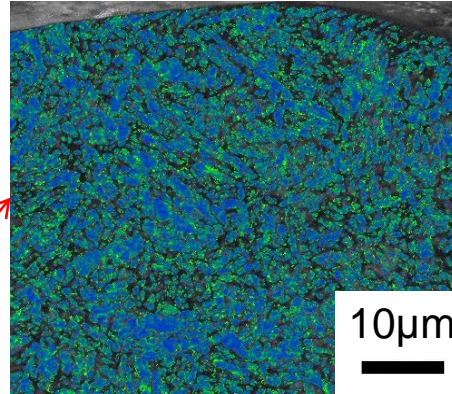
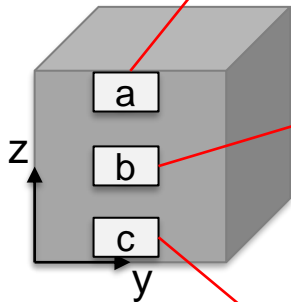


High residual strain

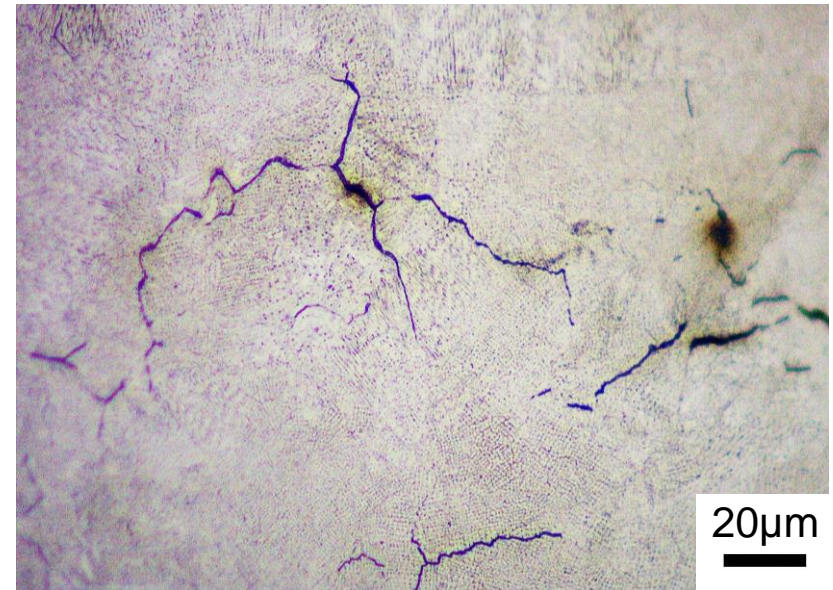
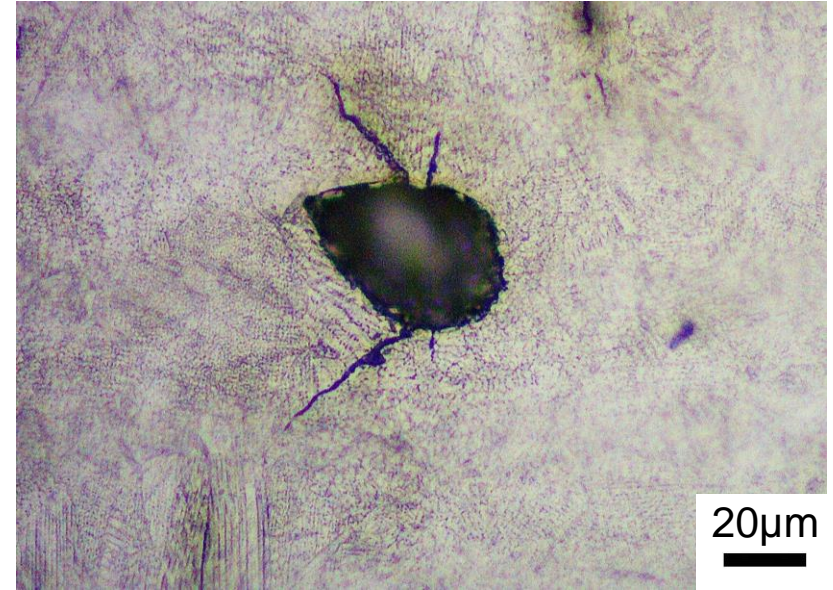
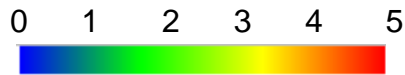


Cracking

Build direction

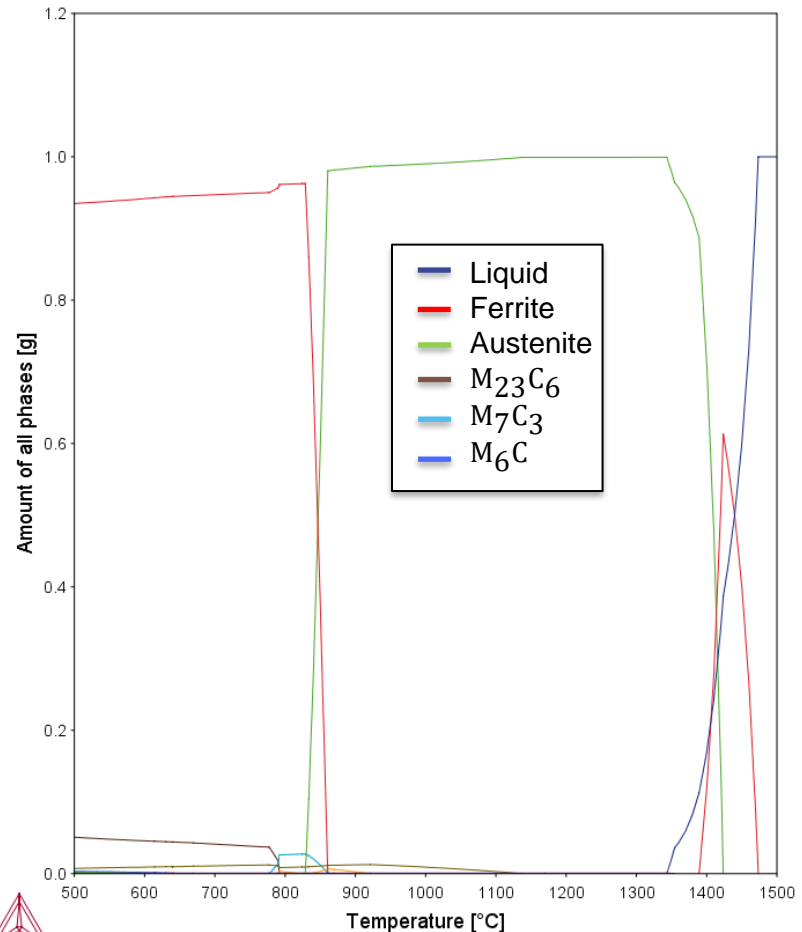
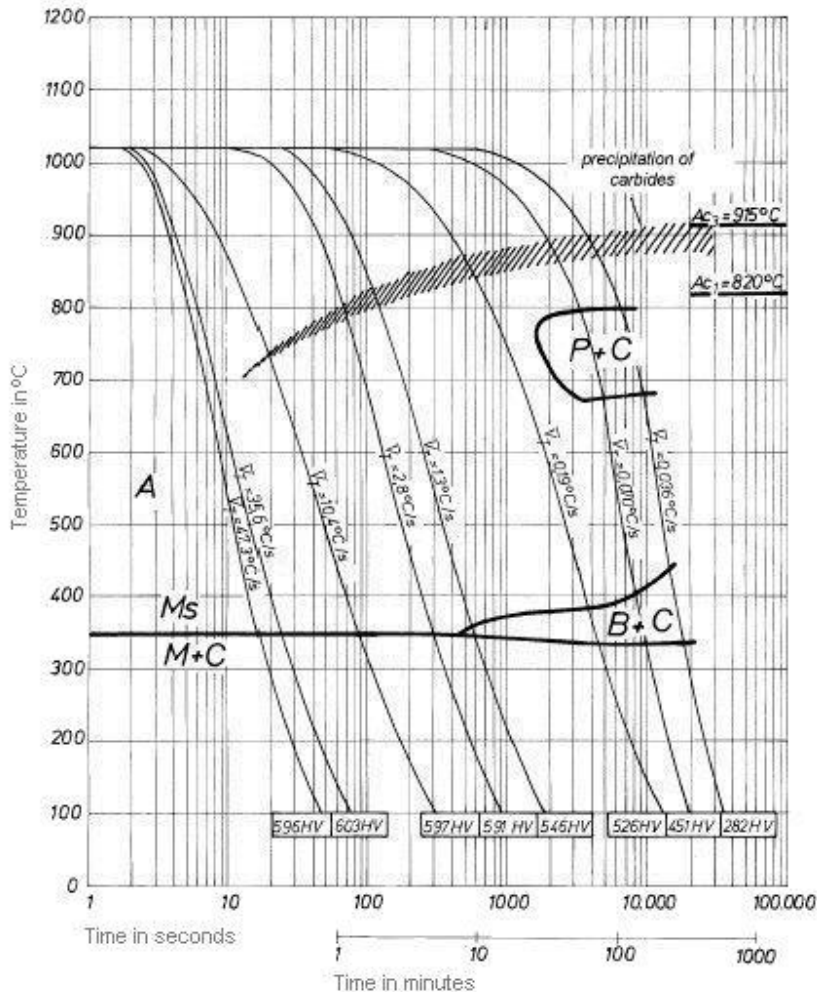


Kernel average misorientation (°)



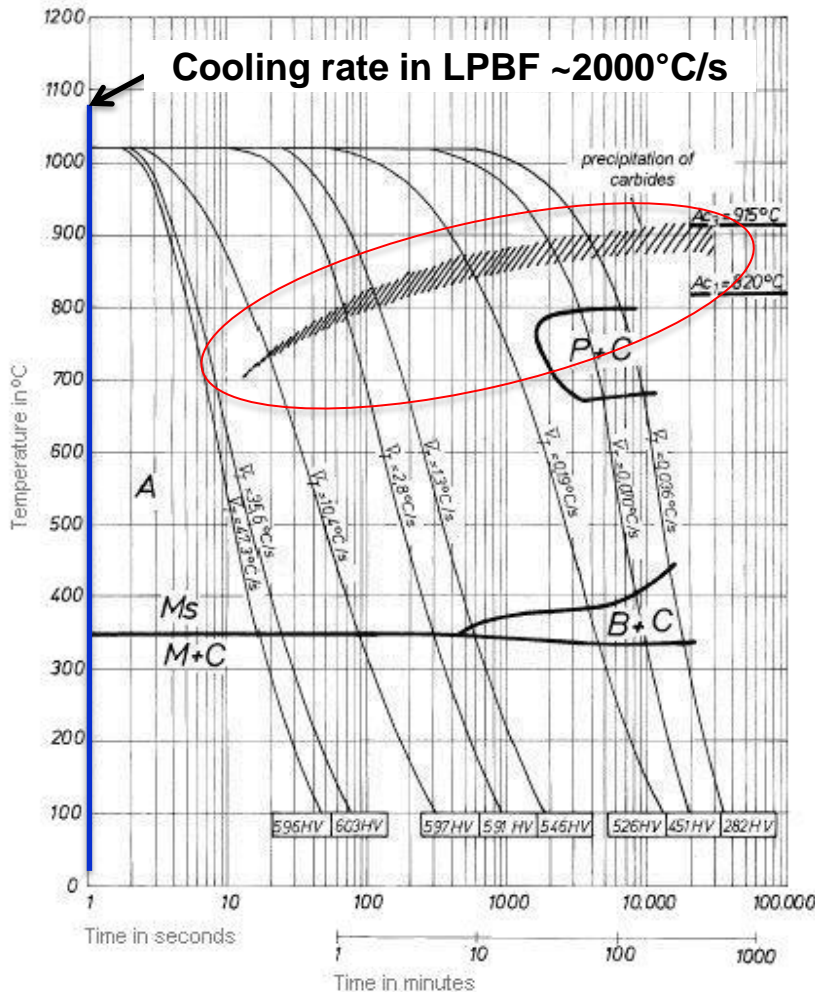
Continuous cooling transformation (CCT) diagram taken from literature

Equilibrium phase-temperature diagram created using Thermocalc software

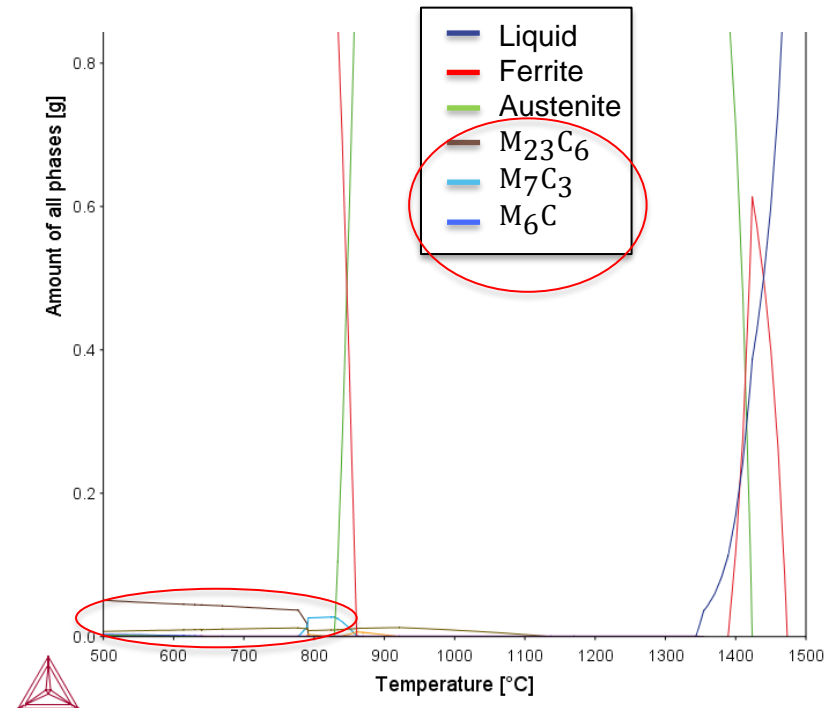


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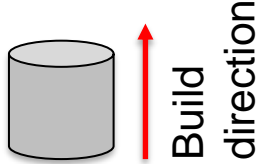


Primary carbide phase:
Chromium rich $M_{23}C_6$
Secondary carbide phases:
Chromium rich M_7C_3
Molybdenum rich M_6C



Sample Creation

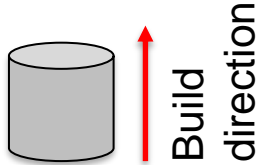
Ø10mm



Samples additively
manufactured
using RenAM 500E

Sample Creation

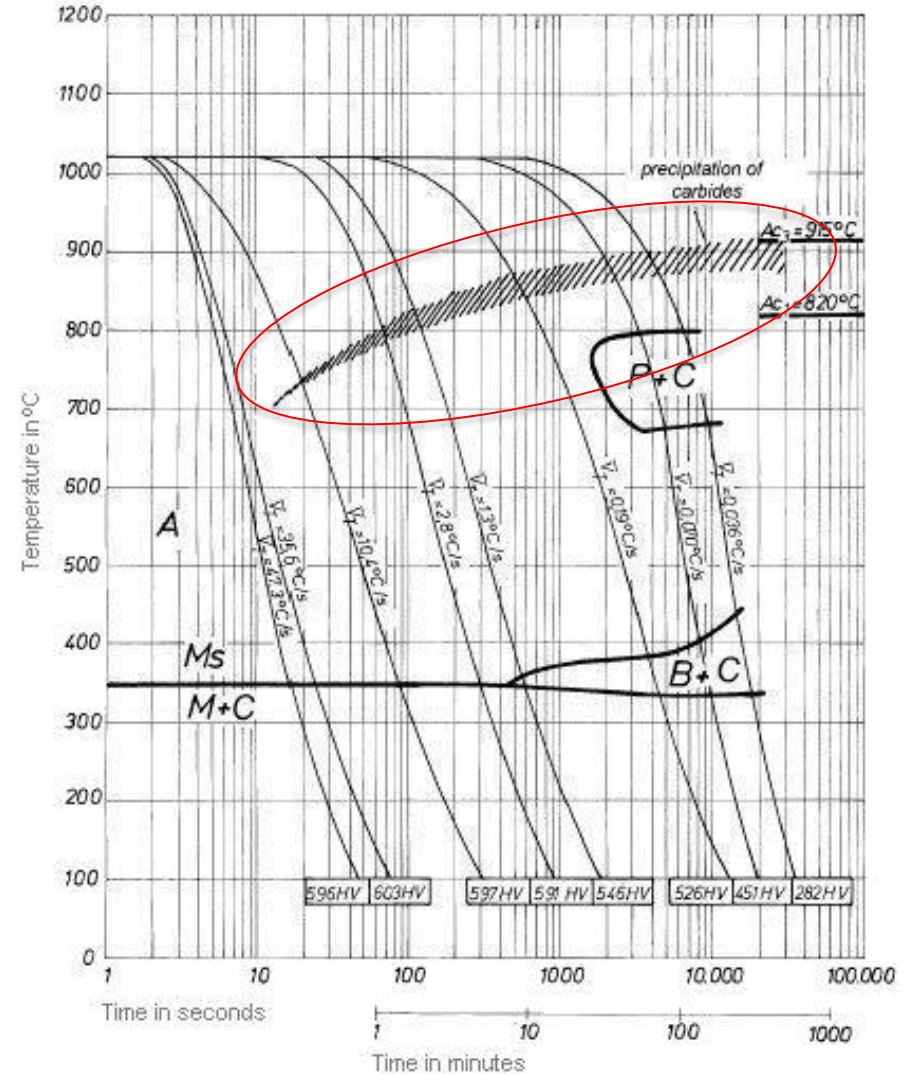
Ø10mm



Samples additively manufactured using RenAM 500E

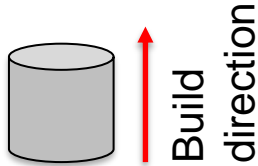
Dilatometry used to apply heat treatments to samples

Control	
Test 1	
Test 2	
Test 3	
Test 4	



Sample Creation

Ø10mm



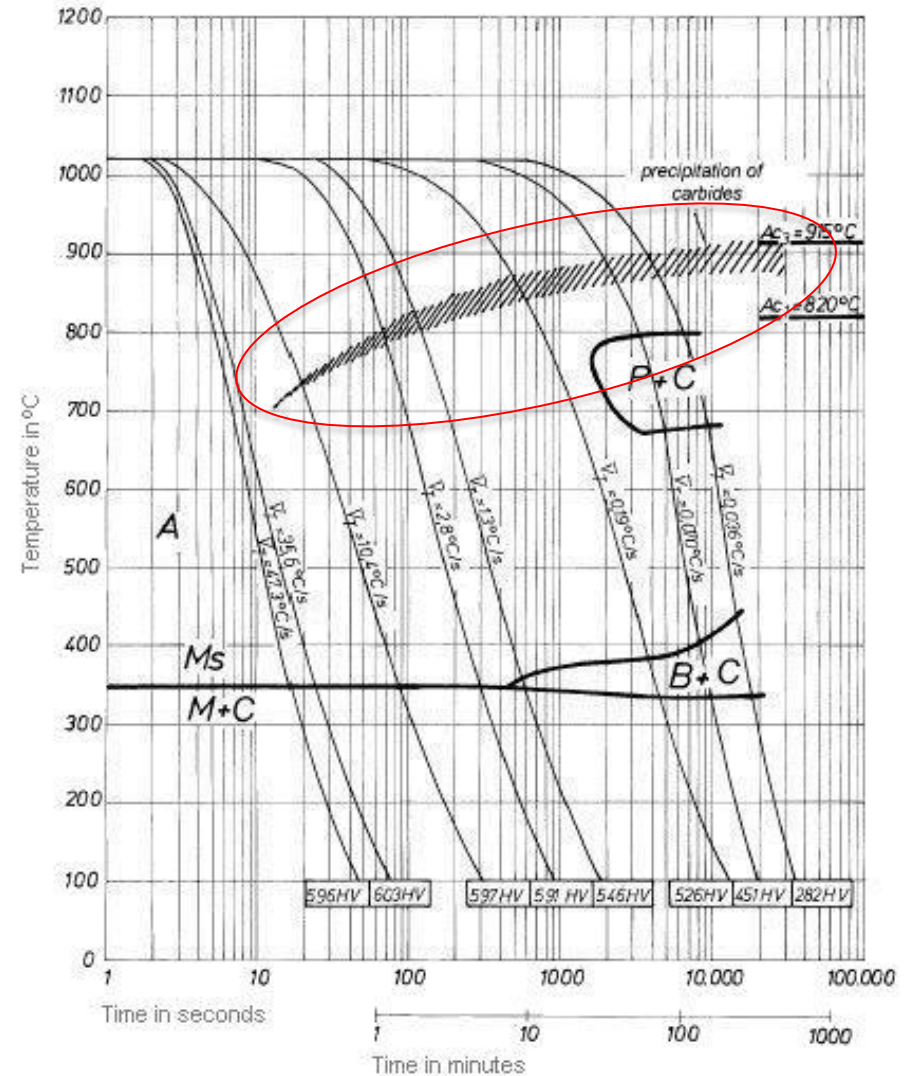
Samples additively manufactured using RenAM 500E

Dilatometry used to apply heat treatments to samples

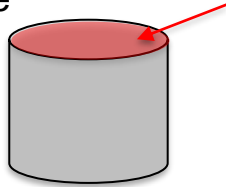
Control	
Test 1	
Test 2	
Test 3	
Test 4	

Sample Characterisation

- Vickers hardness (HV5)
- Scanning electron microscopy backscatter imaging
- Energy dispersive X-ray spectroscopy (EDS)
- Ion beam imaging for quantification

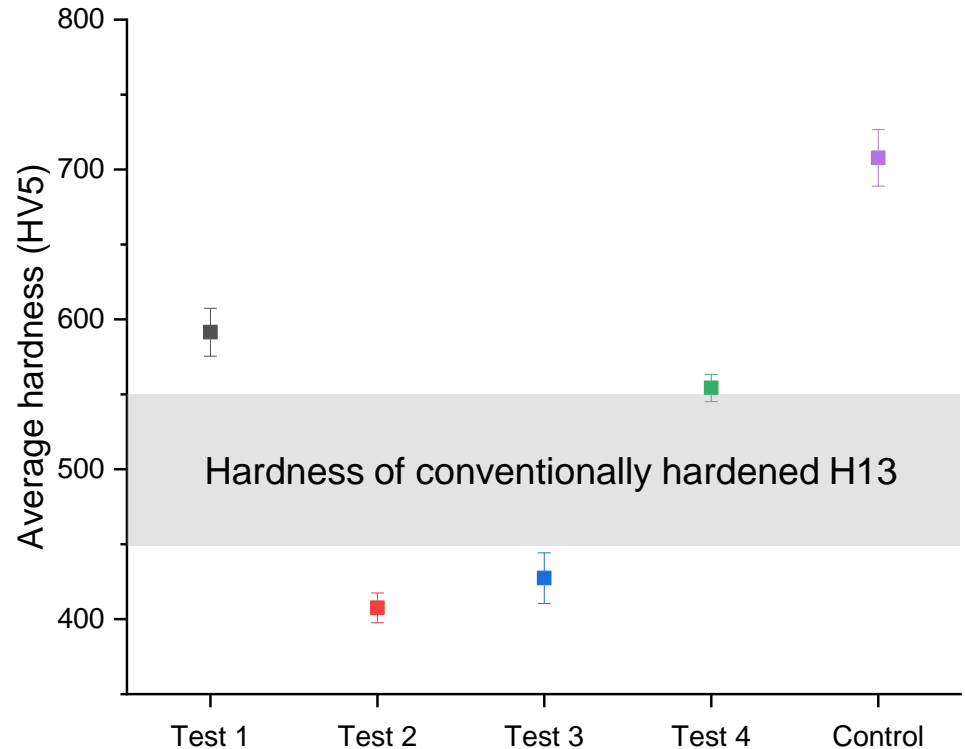
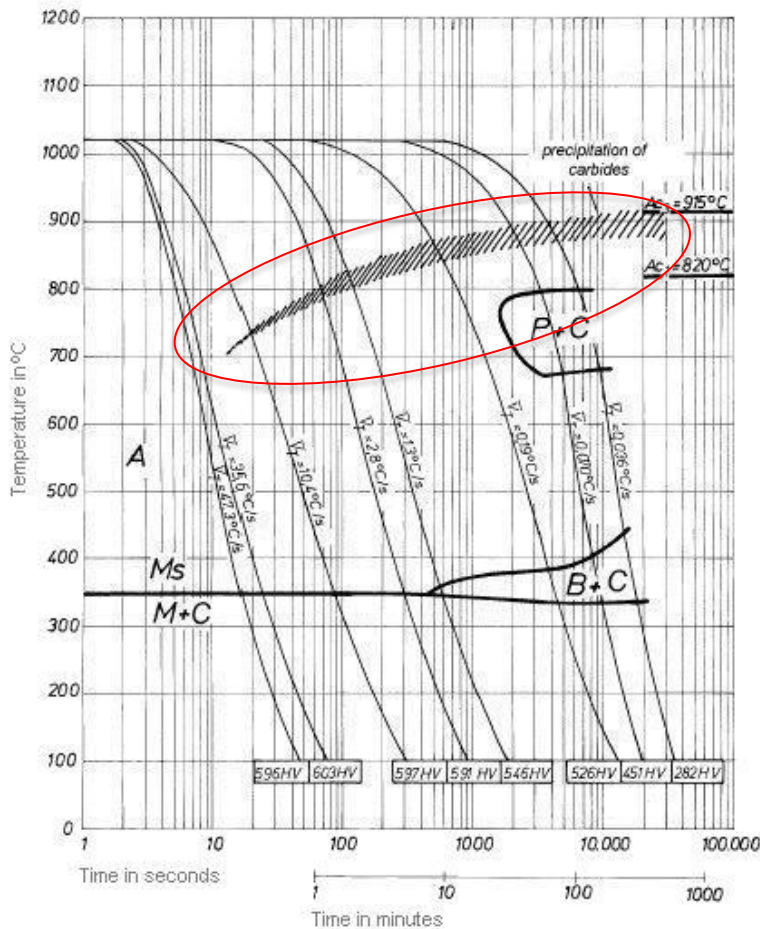


Sample

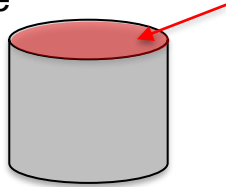


Average hardness taken across 10 measurements from highlighted face

Error bars represent standard deviation of measurements taken

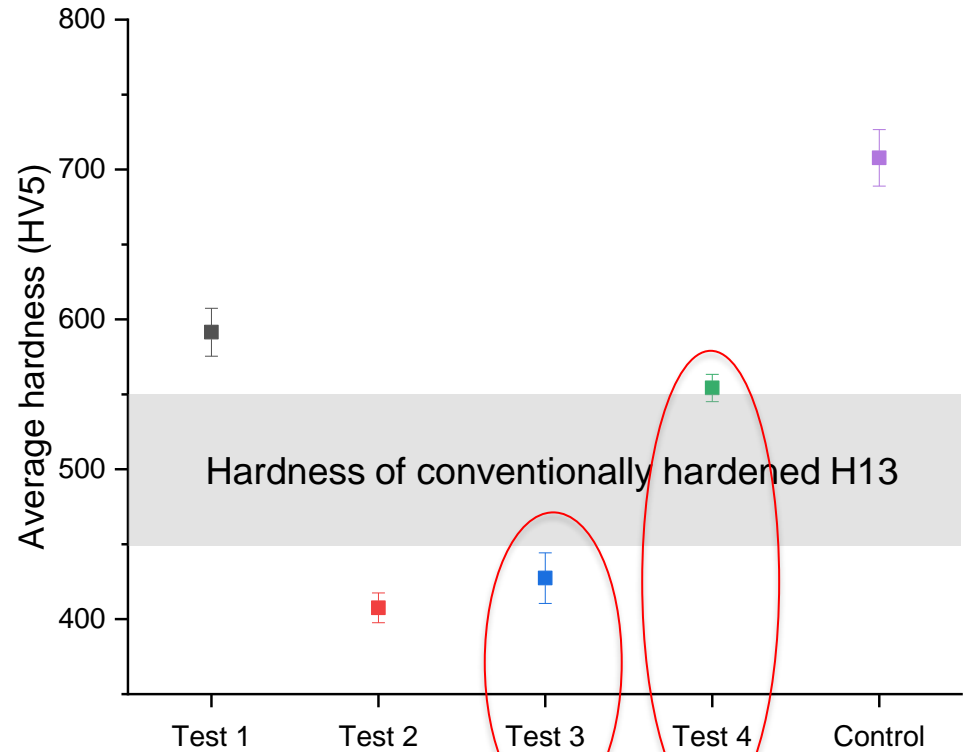
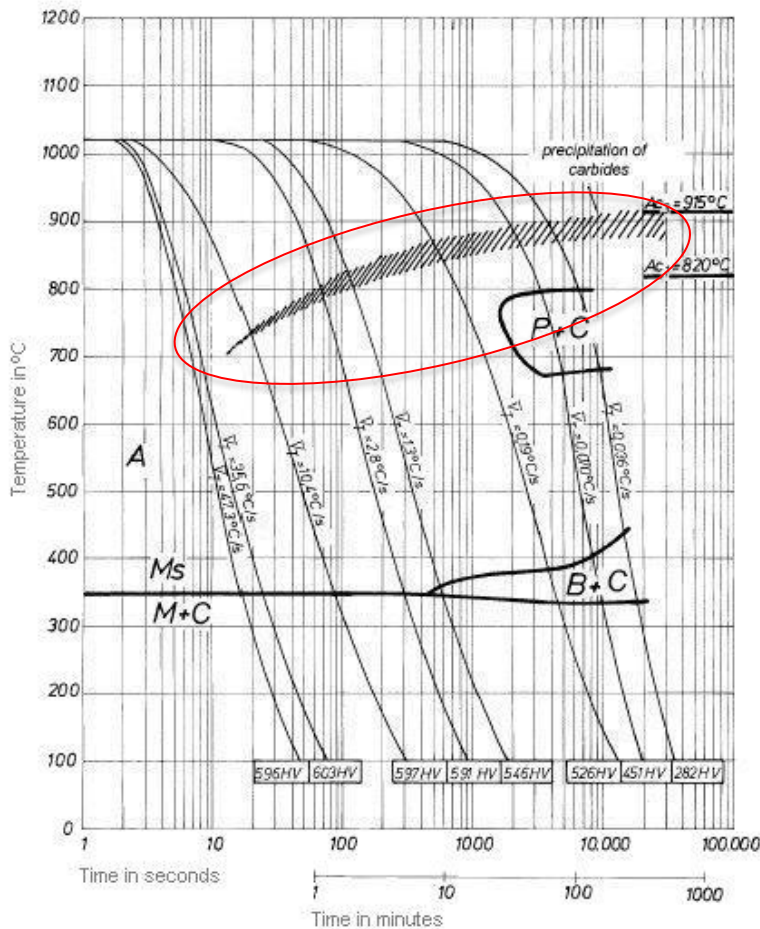


Sample

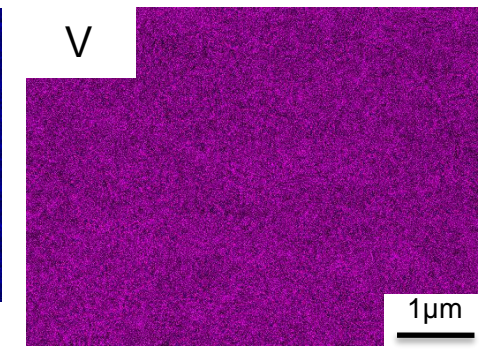
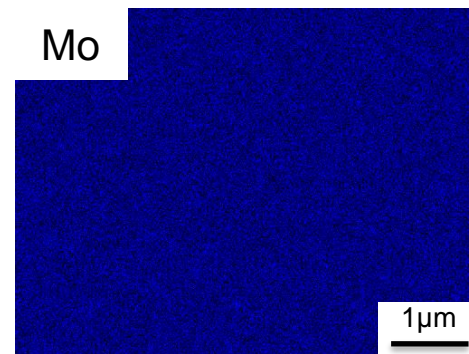
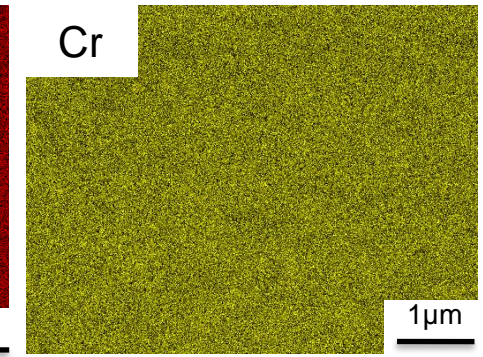
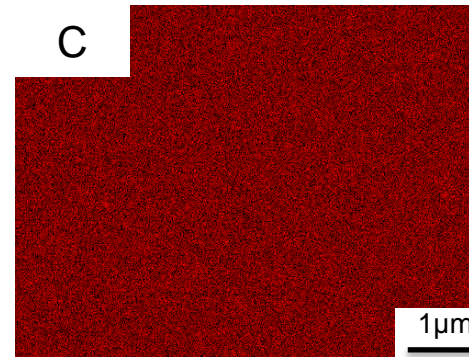
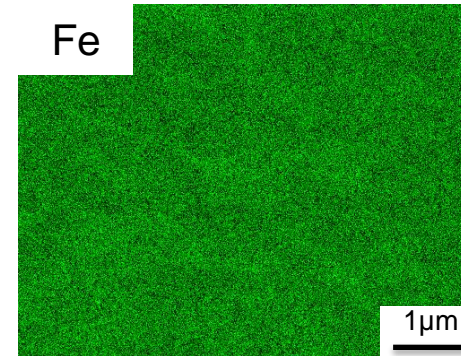
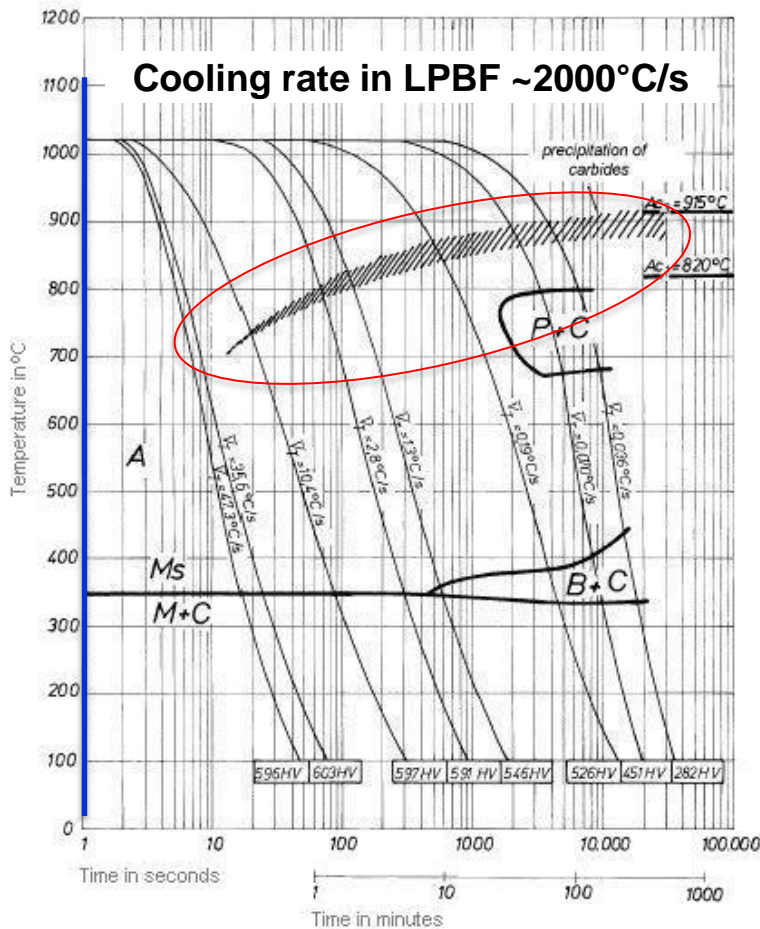


Average hardness taken across 10 measurements from highlighted face

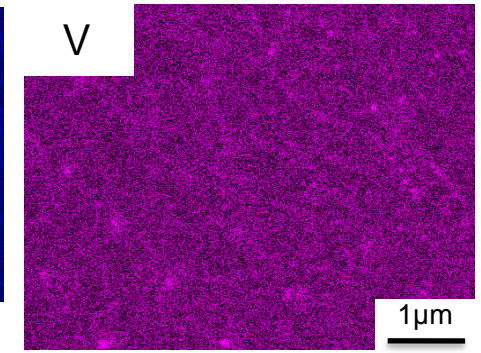
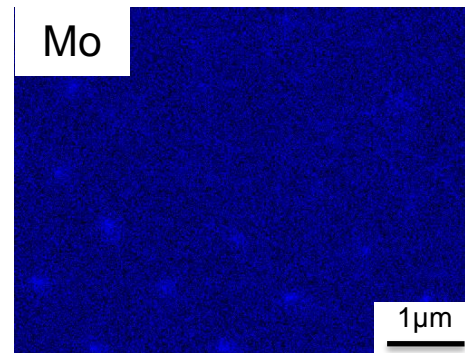
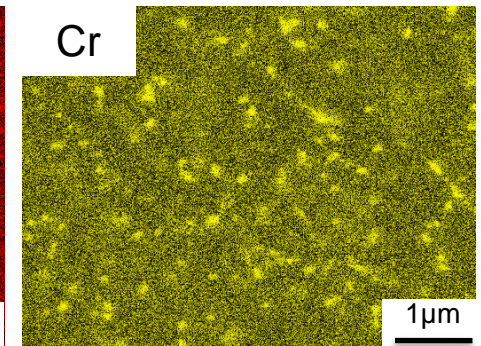
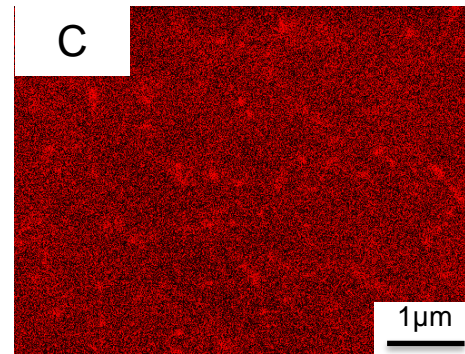
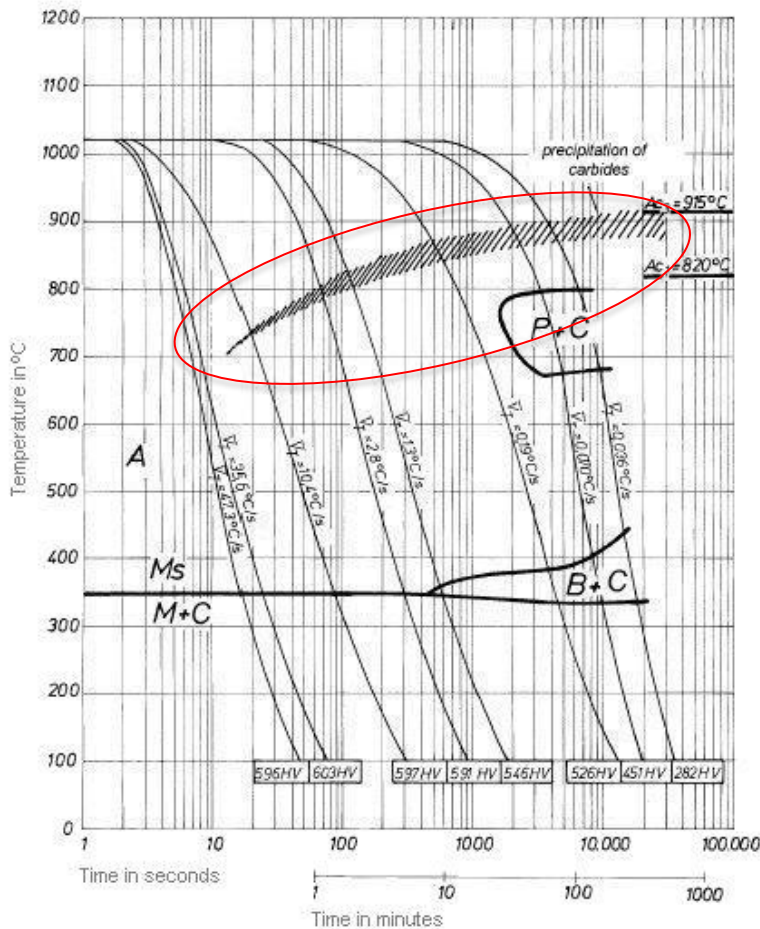
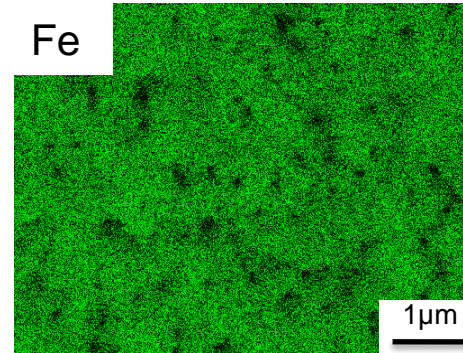
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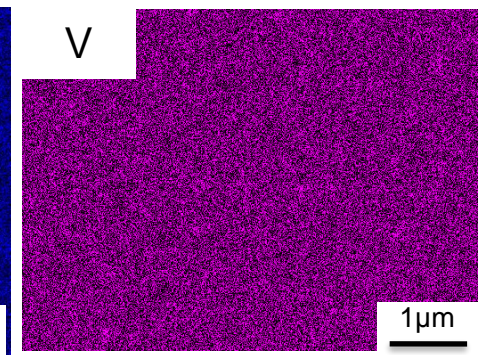
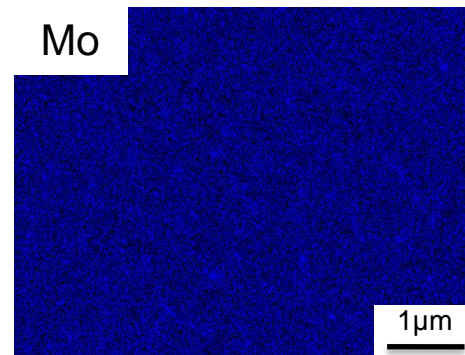
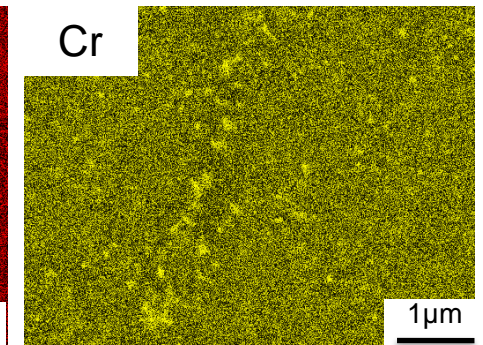
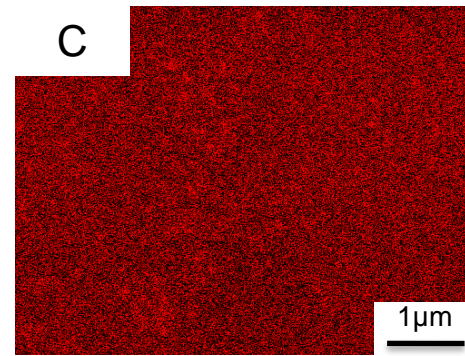
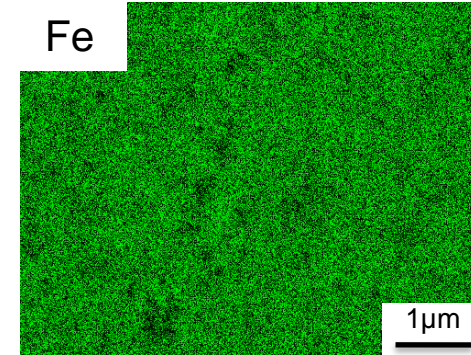
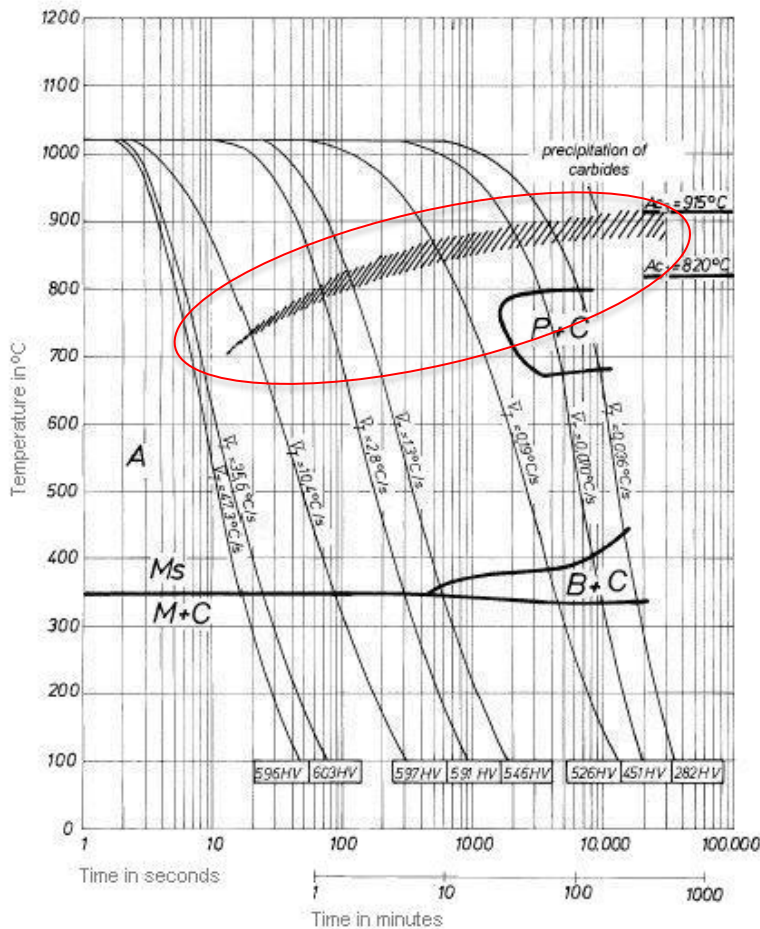
Control: As built, no heat treatment applied
 Accelerating voltage 10kV



Test 3: High temperature, short holding time
 Accelerating voltage 10kV

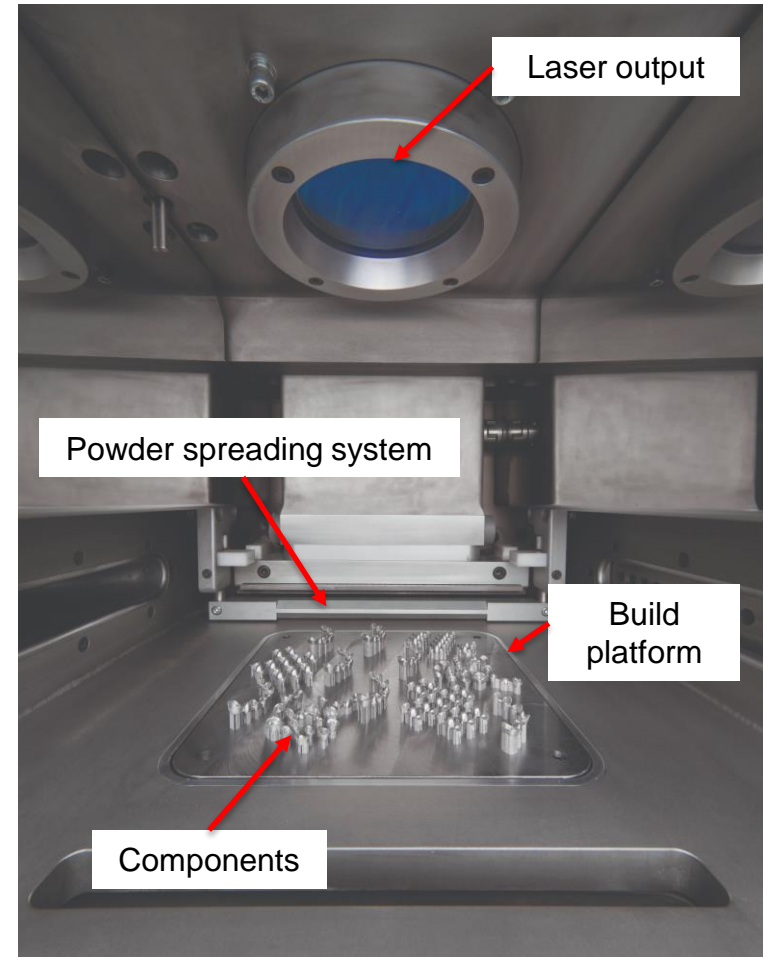


Test 4: Low temperature, long holding time
 Accelerating voltage 10kV



Challenge: time vs temperature

- Service temperatures of ancillary components in the build chamber
- Effects of residual heating to surrounding material
- Limitations of a Gaussian laser beam distribution
- At what point is the heat treatment applied?



Photograph of a RenAM250 build chamber, sourced from [https://resources.renishaw.com/details/AM250+Dental+build+plate\(59498\)](https://resources.renishaw.com/details/AM250+Dental+build+plate(59498))

- Preventative measures are needed to avoid large scale crack propagation in tool steel alloy H13 components fabricated by LPBF AM*
- Short term, high temperature heat treatments can transform H13's undesirable AM microstructure to resemble conventionally processed H13
- This has the effect of reducing hardness to levels which also resemble conventionally processed H13
- Further research to be conducted to incorporate this into a LPBF AM* system

*Laser powder bed fusion (LPBF) additive manufacturing (AM)



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