Ultraljudsteknik för karaktärisering av AM-komponenter

Ultrasound QNDE of additively manufactured components

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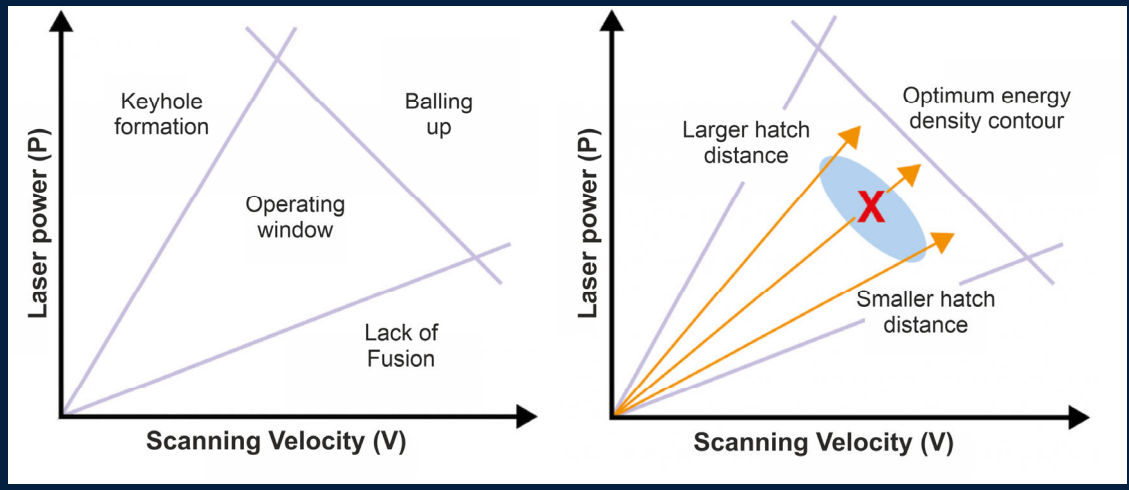
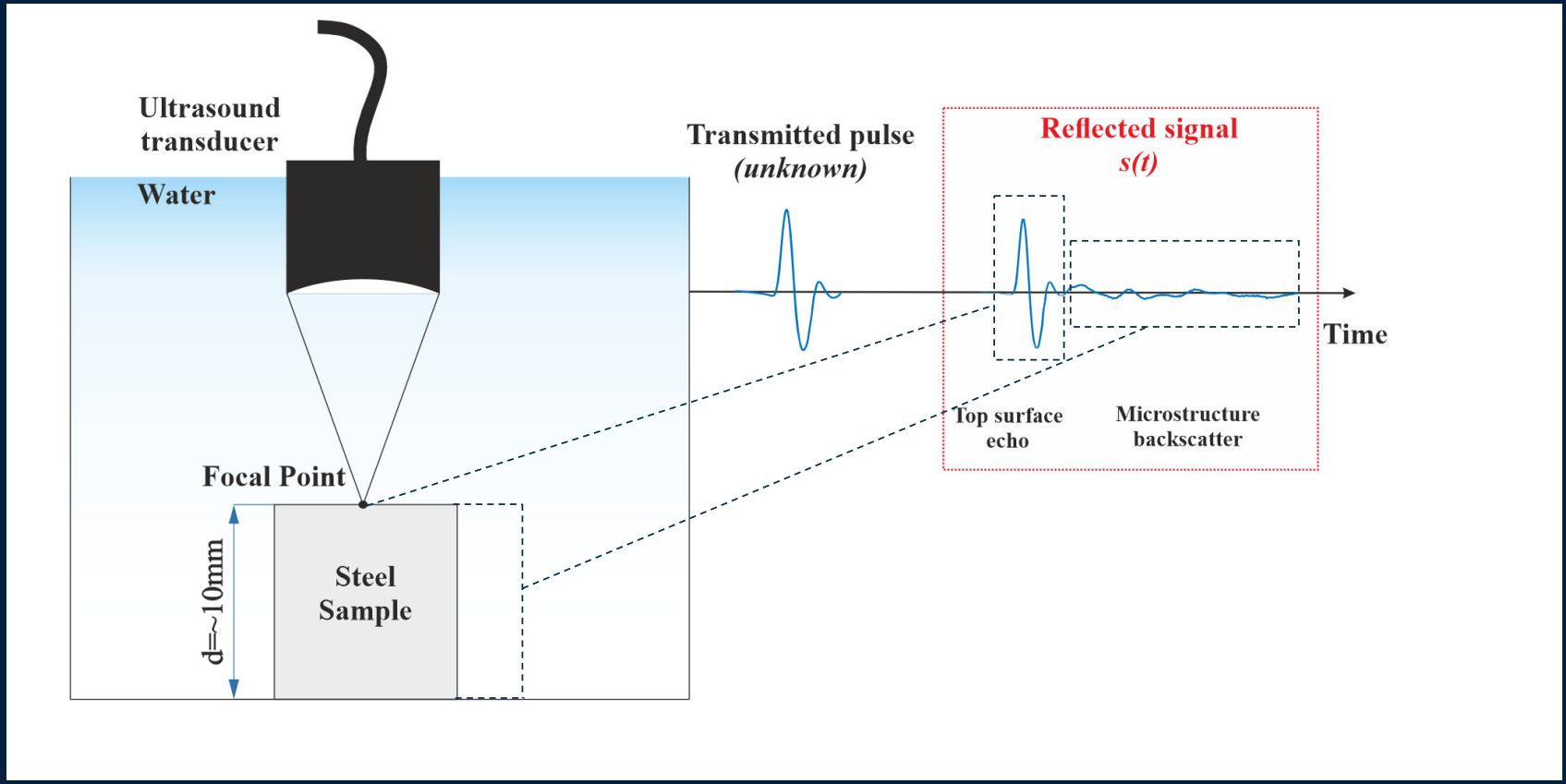
Additive Manufacturing

Fraunhofer ILT

Additive manufacturing of complex parts



Ultrasound


Ultrasound transducer
Water
Transmitted pulse
(unknown)
Reflected signal
s(t)
Time
Top surface echo
Microstructure backscatter
Focal Point
d=~10mm
Steel Sample

Research Motivation

'Can we establish a relationship between ultrasound measurement, manufacturing parameters, and resulting material properties?'

The research question can be explored in the following ways:

- Can ultrasound be linked to the manufacturing parameters, and how can we differentiate between different samples based on ultrasound measurements?
- What is the influence of the manufacturing parameters on the variation in ultrasound captured from the AM samples?
- How to quantify the material properties and do quality assessment of samples based on ultrasound measurements?

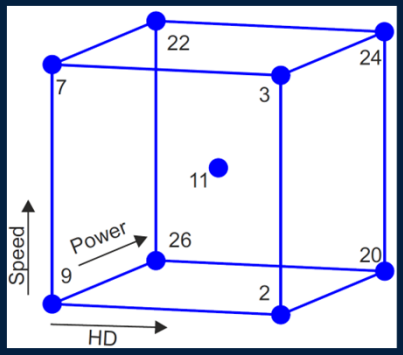
In other words…

Can we replace time-consuming and destructive material characterization with a rapid, non-destructive ultrasound technique?

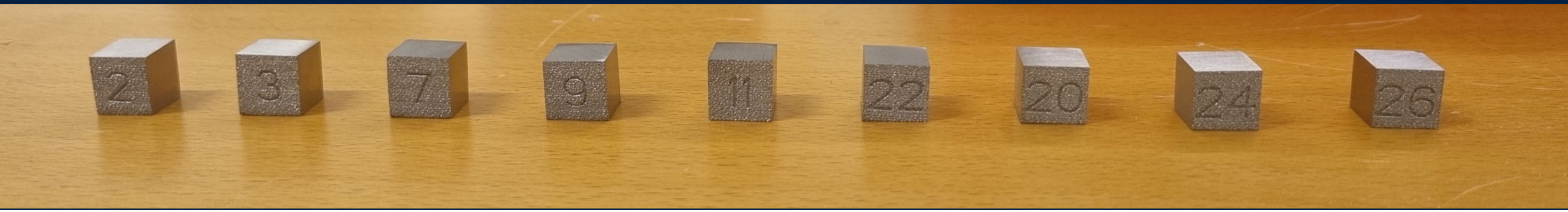
Sample Printing

- Experimental design (selected samples of 316L stainless steel, LBPF)

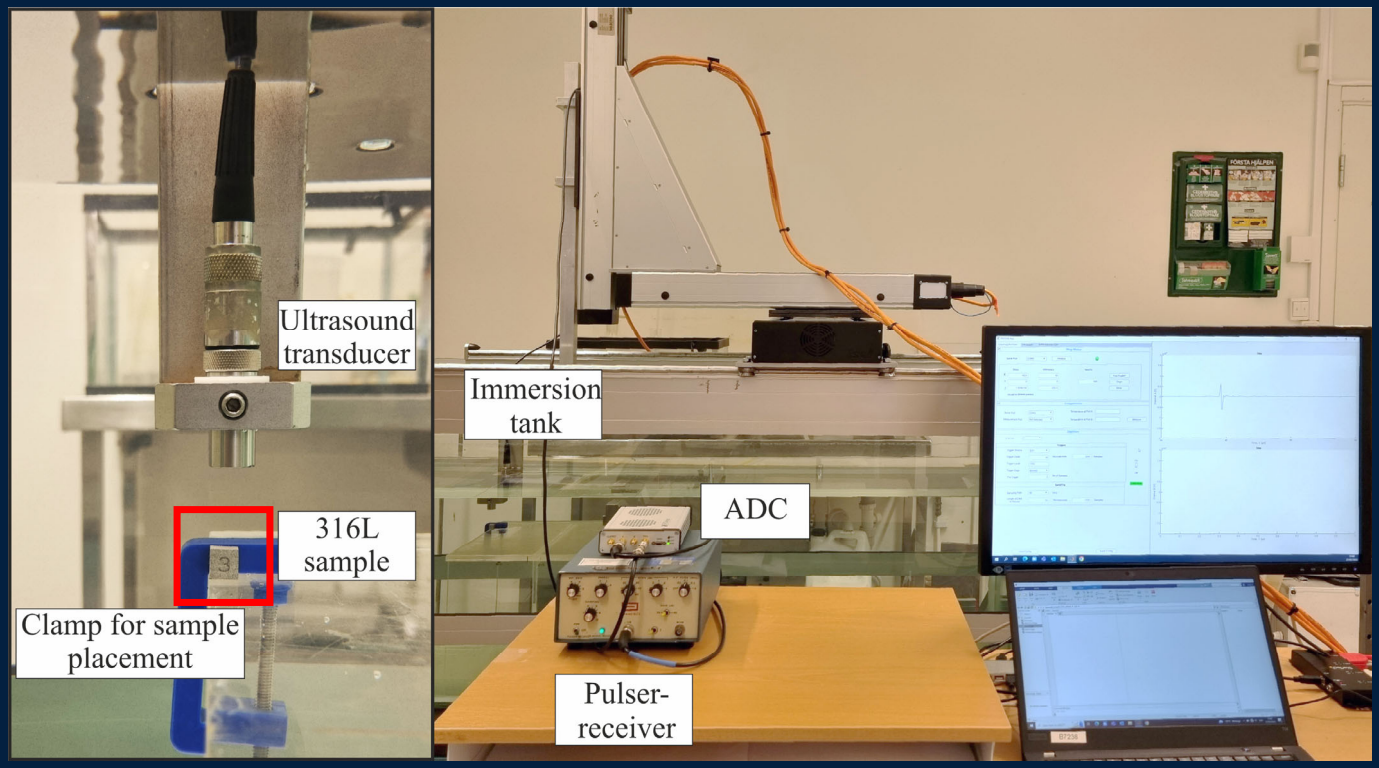
$$VED = \frac{Power}{Speed * HD * LH}$$



Cube	**Power (W)**	LH (µm)	**HD (µm)**	t_E (s)	**Speed (mm/s)**	VED (J/mm³)
9	**195**	50	**90**	80	**600**	72.2222
2	**195**	50	**100**	80	**600**	65
7	**195**	50	**90**	80	**700**	62.90476
3	**195**	50	**100**	80	**700**	55.71429
11	**175**	50	**95**	80	**650**	56.8016
26	**155**	50	**90**	80	**600**	57.40741
20	**155**	50	**100**	80	**600**	51.6667
22	**155**	50	**90**	80	**700**	49.20635
24	**155**	50	**100**	80	**700**	44.28571

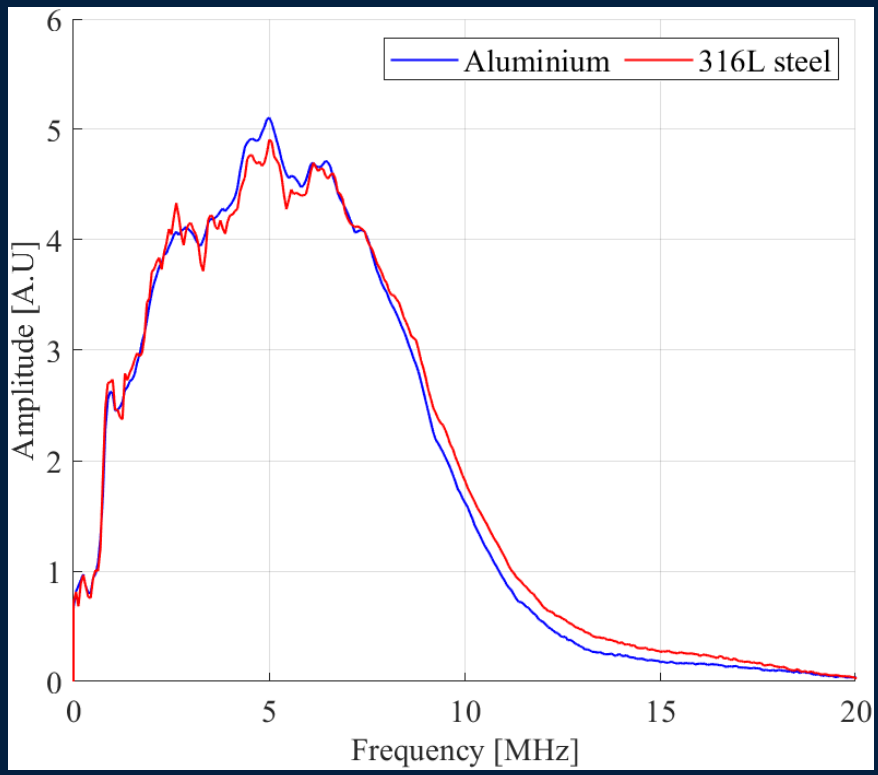


Experimental Setup – Ultrasound



Ultrasound Measurements

- Samples examined using 5 MHz and 7.5 MHz focused transducers.
- Data is collected from the build and transverse direction.
- Ultrasound echoes from 841 points were recorded for each sample.
- Ultrasound spectra computed for each recorded echo.



The supervised learning problem

Ultrasound data

Material properties
or process information

Examples

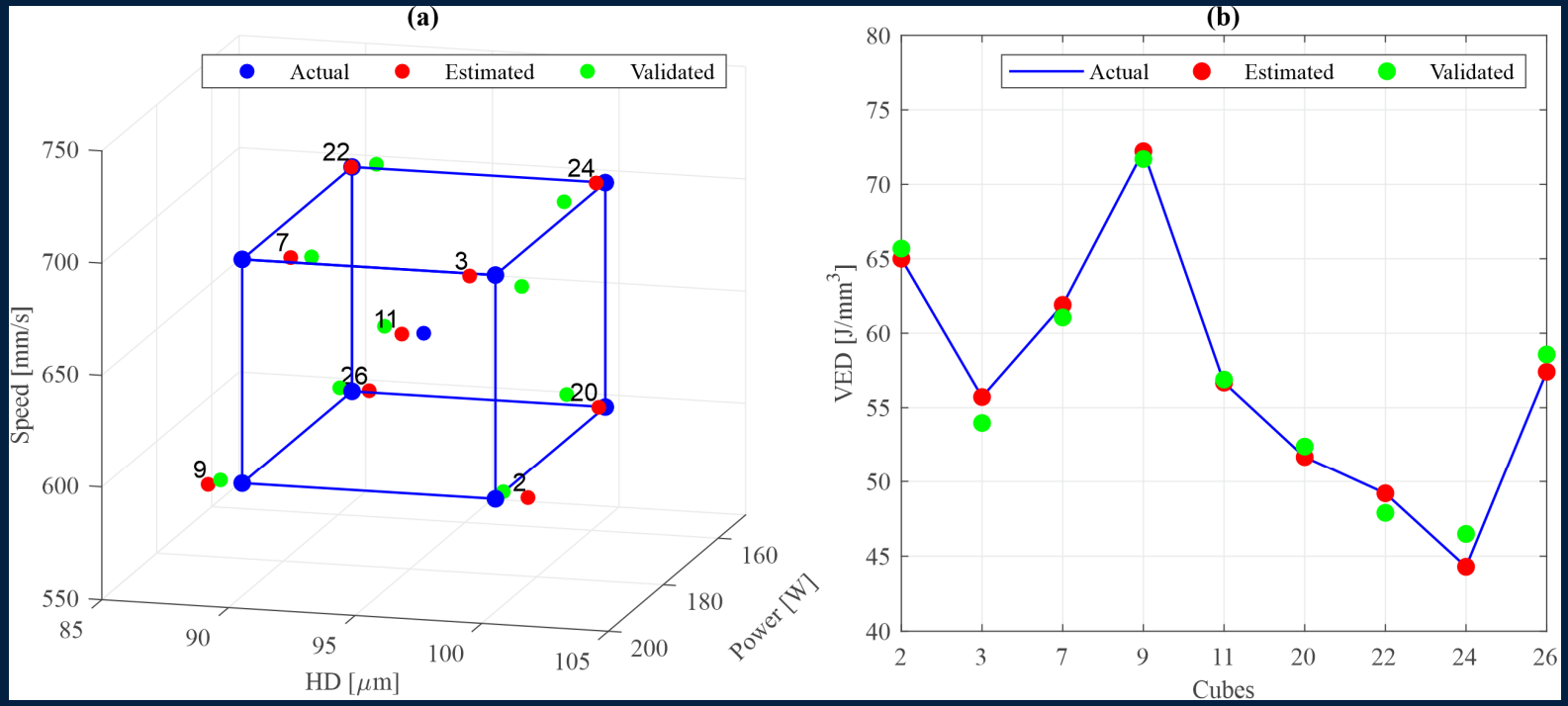
- Linking the manufacturing parameters to ultrasound.
- Assessing the influence of the manufacturing parameters on variability within samples, based on ultrasound data.
- Linking the material properties to ultrasound data.

Modelling the parameters

- Data randomly split into two data sets
  - Training
  - Testing
- A model is built for estimation of manufacturing parameters from ultrasound spectra.
-

Results

Estimation and validation of manufacturing parameters using 5 MHz transducer in build direction.



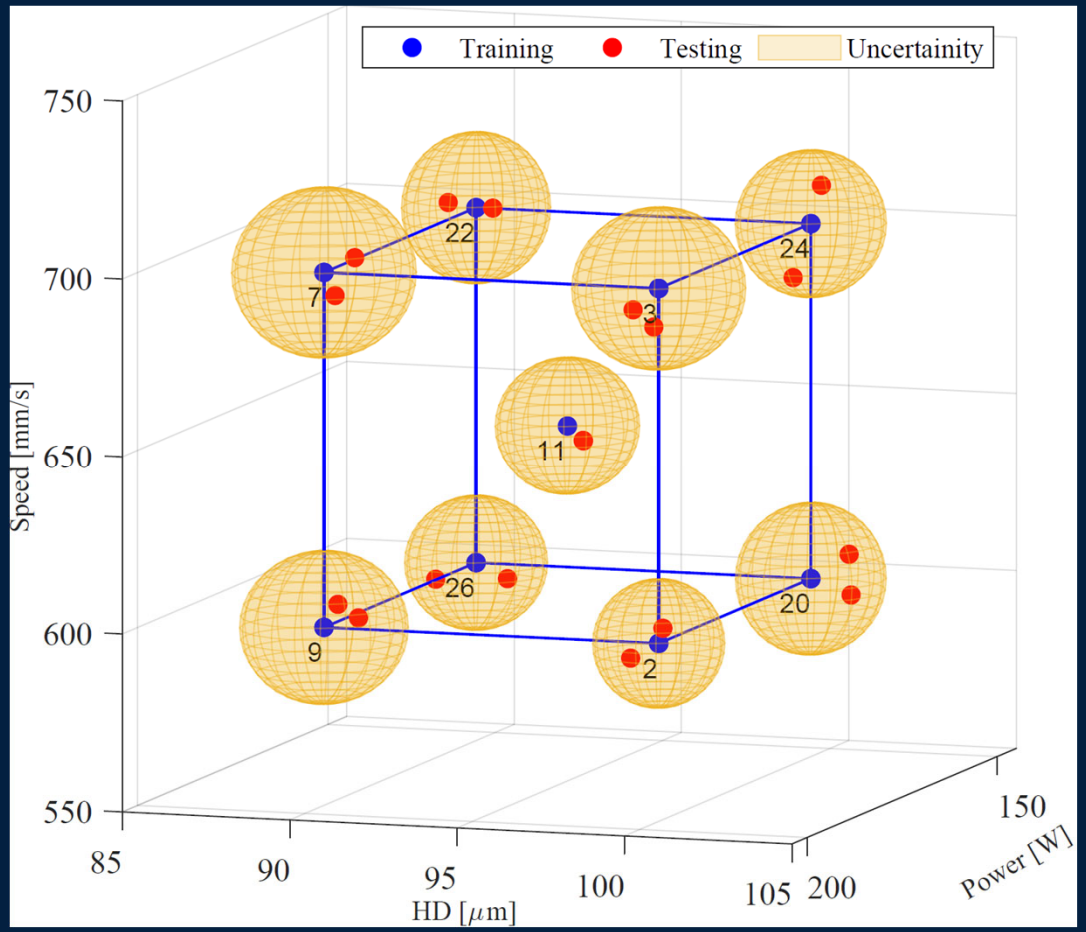
Assessing the uncertainty

Monte-Carlo simulations

- Variations in ultrasound spectra used to build multiple prediction models.
- Comparing models to assess the prediction error variance.

Results

Prediction of manufacturing parameters using 5 MHz transducer in the build direction.

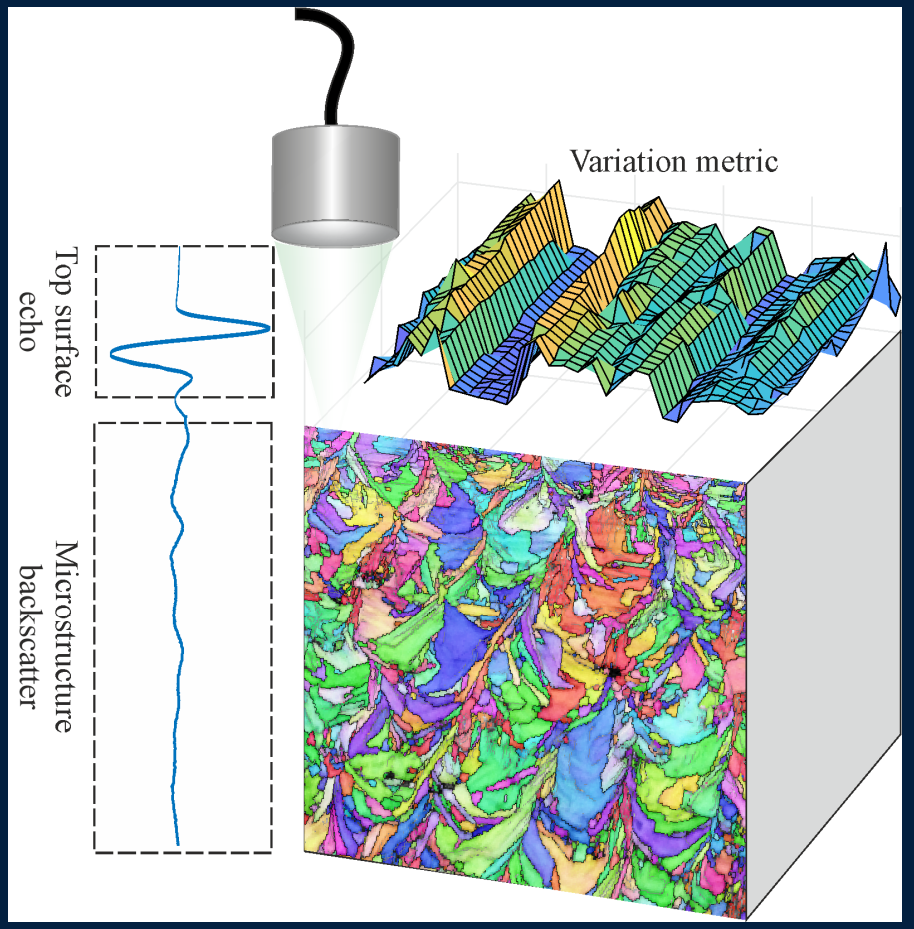


Examples

- Linking the manufacturing parameters to ultrasound.
- Assessing the influence of the manufacturing parameters on variability within samples, based on ultrasound data.
- Linking the material properties to ultrasound data.

Variability of microstructur backscatter

- Idea:
  - If a sample is a homogeneous isotropic solid, the backscatter statistics should be consistent across a sample.
  - Large variation in ultrasound is an indication of large variations in microstructure.
- Linking ultrasound variation to manufacturing parameters… possible way to fine-tune the process.

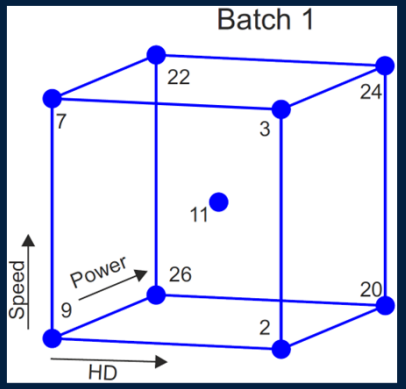


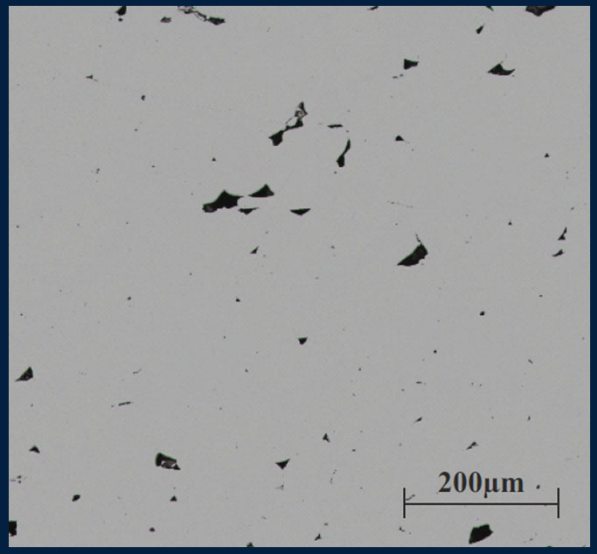
Examples

- Linking the manufacturing parameters to ultrasound.
- Assessing the influence of the manufacturing parameters on variability within samples, based on ultrasound data.
- Linking the material properties to ultrasound data.

Material Characterization

- Porosity Analysis
- Hardness Testing
- Texture Analysis
- Grain Size Measurements





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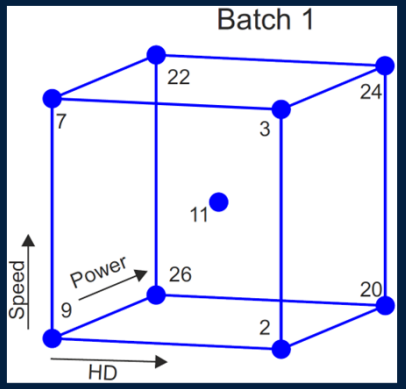

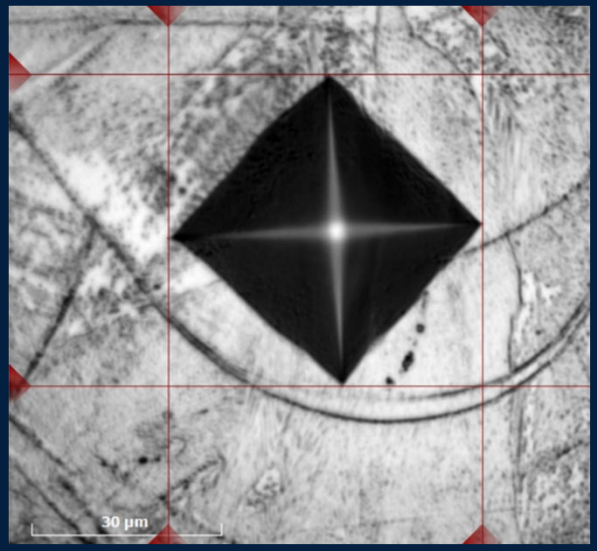

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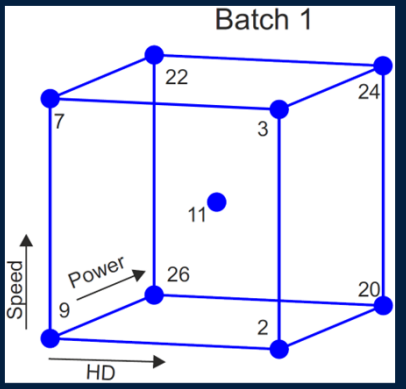

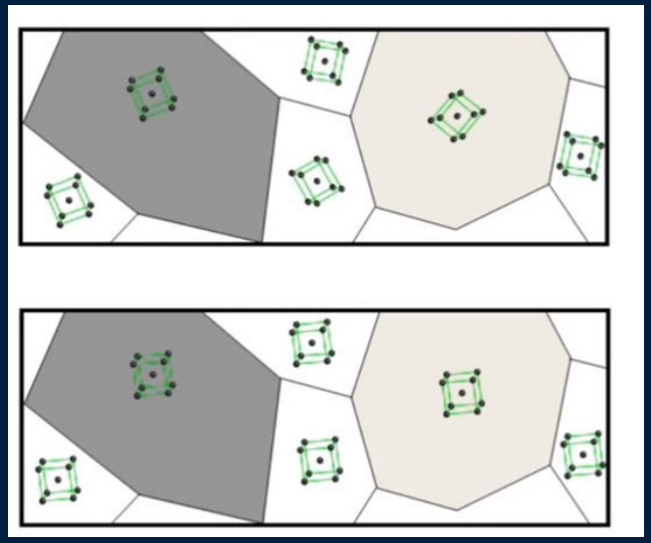

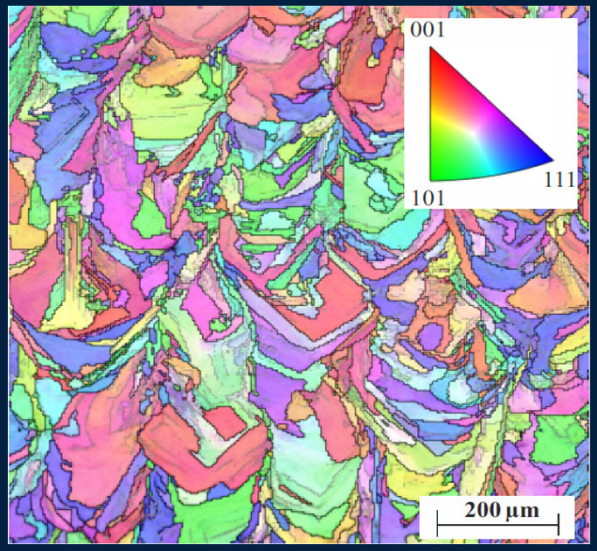

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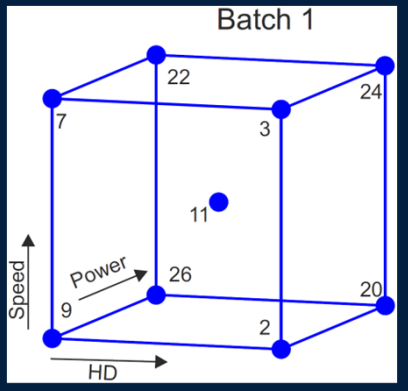
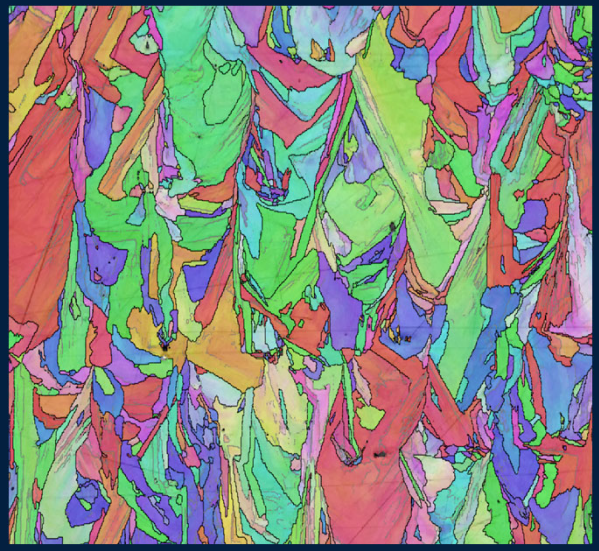
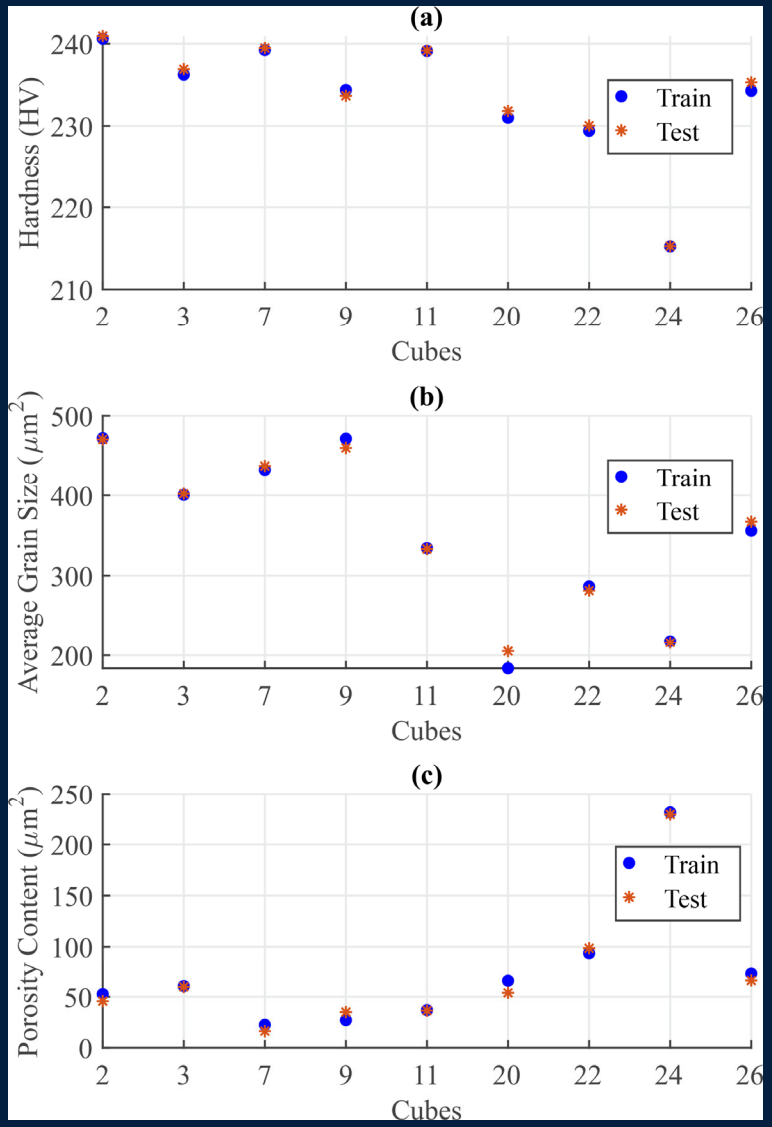




Prediction of Material Properties

- Hardness porosity and grain size
- Porosity
- Grain size

Uncertainties (±2σ)			
Sample	**Hardness**	**Grain Size**	**Porosity**
2	0.123574	2.112873	1.143406
3	0.125587	2.20308	1.162037
7	0.12235	2.159209	1.148282
9	0.123678	2.226281	1.175446
11	0.127918	2.215124	1.184591
20	0.120423	2.131117	1.112265
22	0.120019	2.165733	1.127722
24	0.122276	2.105198	1.1317
26	0.124037	2.234214	1.16994



Acknowledgements

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Thank you!

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