Introduction to grain size measurement using LUMet

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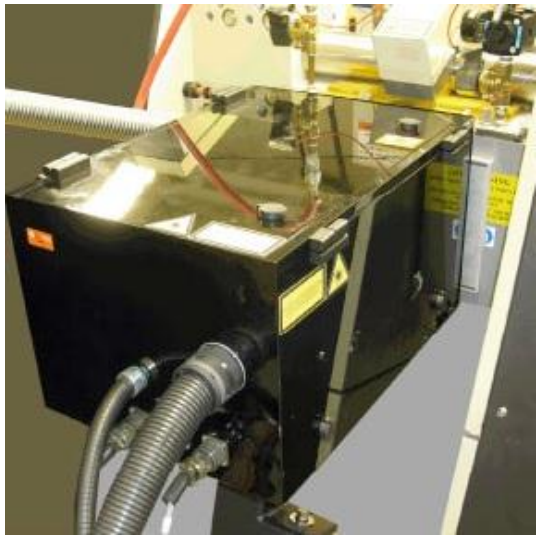
Acknowledgment

A commercial sensor for metallurgist

- ✓ Laser Ultrasonics for Metallurgy (LUMet)
- ✓ Attachment to a Gleeble thermo-mechanical simulator
- ✓ Dedicated sensor for measurements during processing of metals



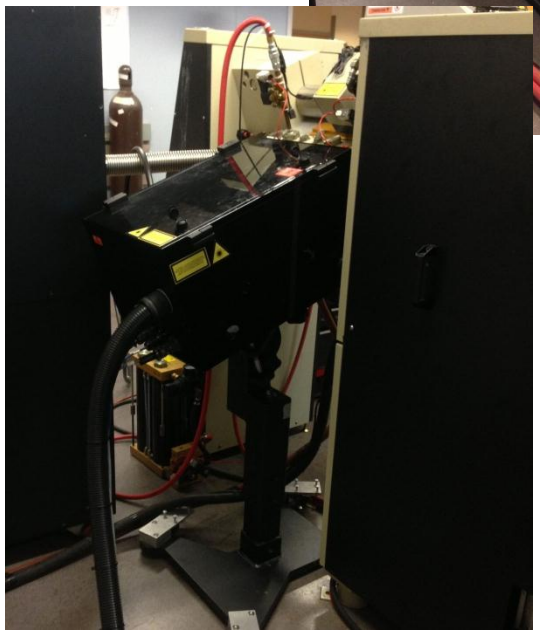
NRC·CNRC
Industrial Materials Institute

TECNAR

DSI®
Dynamic Systems Inc.

LUMet : Technical specifications

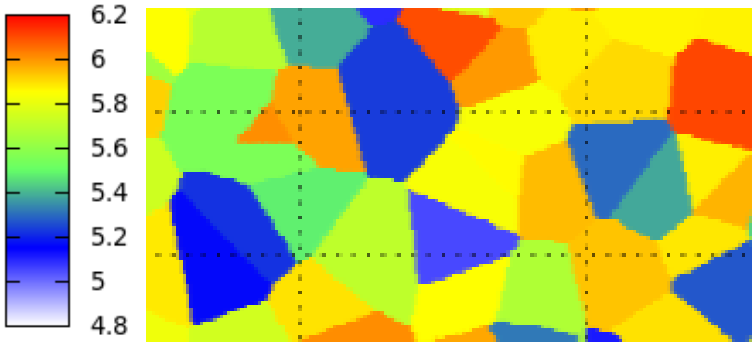
- ✓ Generation pulse laser: Frequency double Q-switch Nd:YAG (532nm, 72mJ, 9 ns)
- ✓ Detection pulse laser: Frequency stabilized Nd:YAG (1064nm, 90 µs)
- ✓ Photorefractive interferometer
- ✓ Bandwidth: 4 to 20 MHz
- ✓ Up to 50 pulses per second



Why attenuation relates to grain size ?

- ✓ Relatively anisotropic material
- ✓ Large mismatch in the elastic properties from grain to grain
- ✓ Attenuation : Diffraction + scattering + internal friction
- ✓ Experiments and theories agree on the existence of scattering regimes

Velocity map



$$\alpha(f) = C(T)D^{n-1}f^{n}$$

$$\lambda >> D\ ,\ n = 4$$

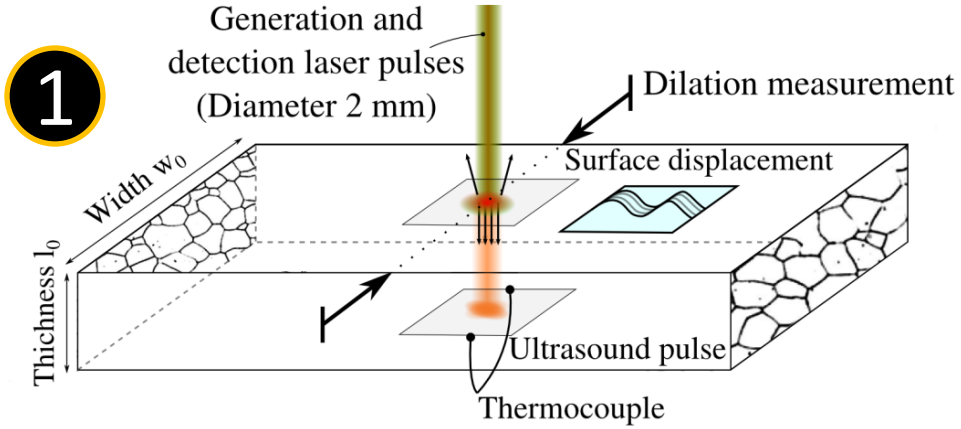
$$\lambda \approx D\ ,\ n = 2$$

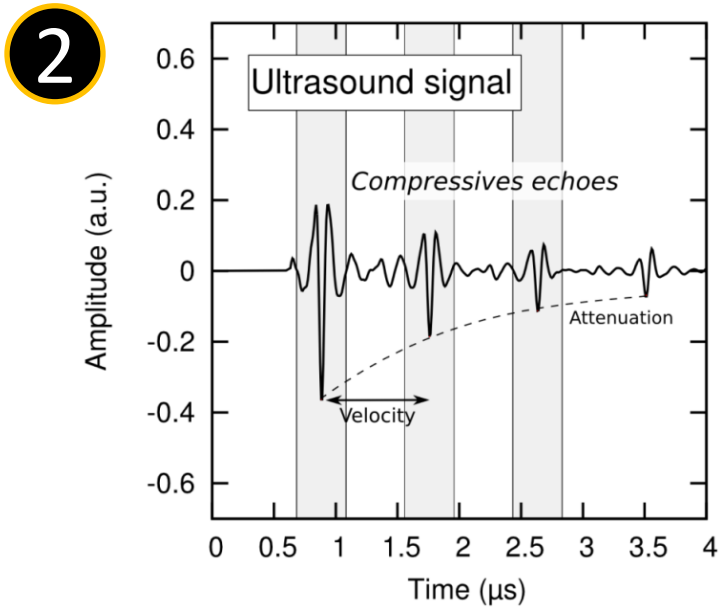
LUMet in steel

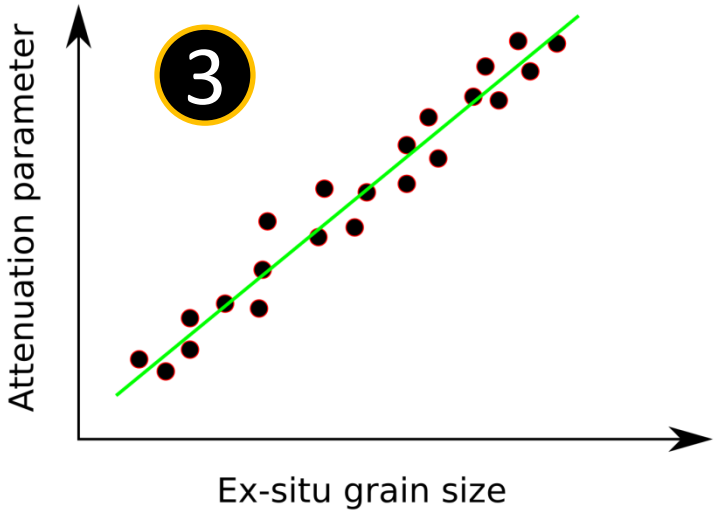
$300 < \lambda < 1000$ (µm)

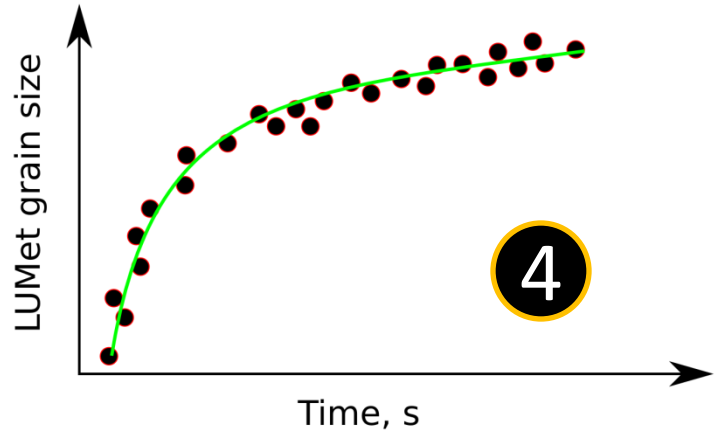
$5 < D < 500$ (µm)

Measure grain size with LUMet



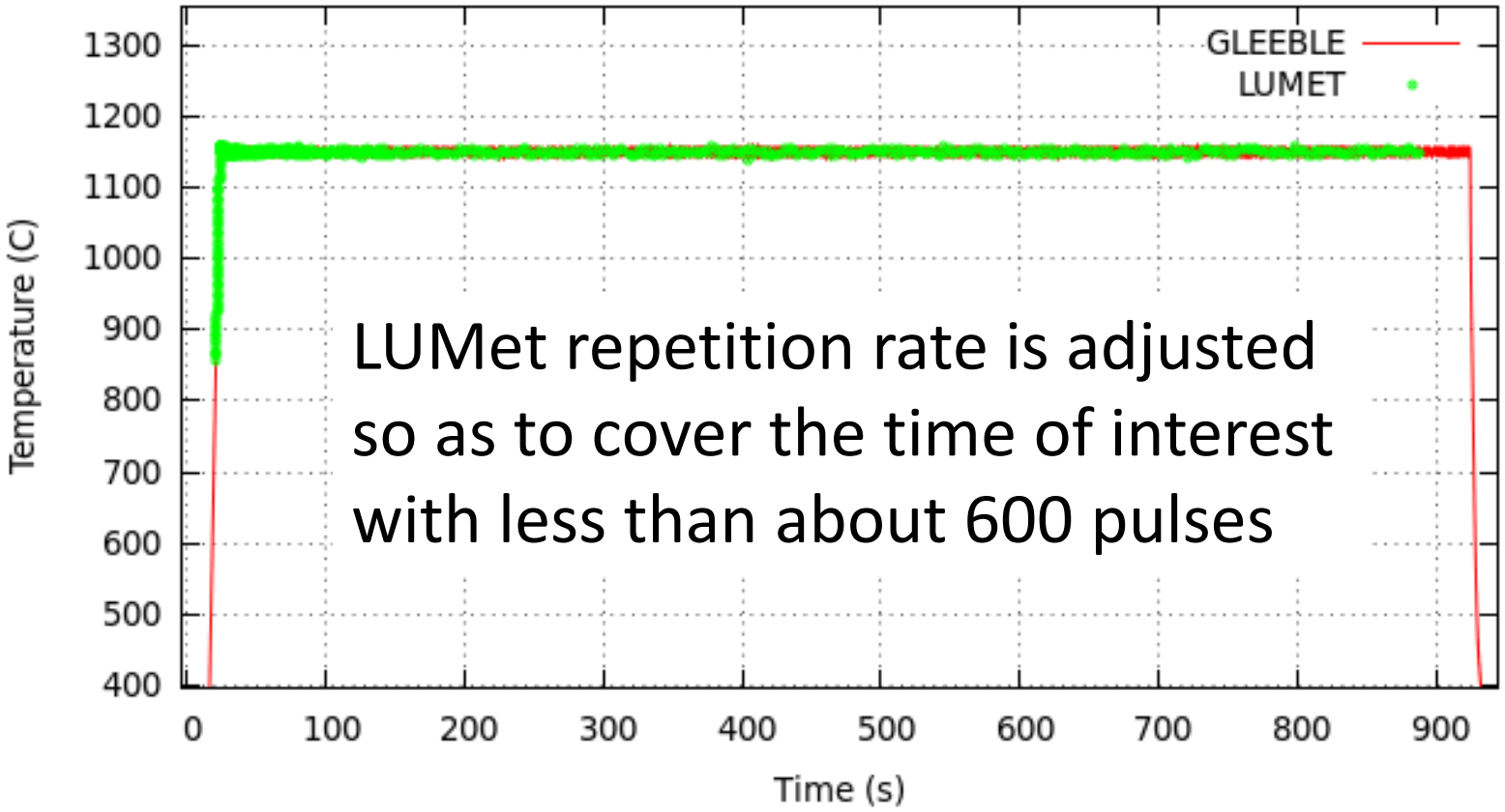




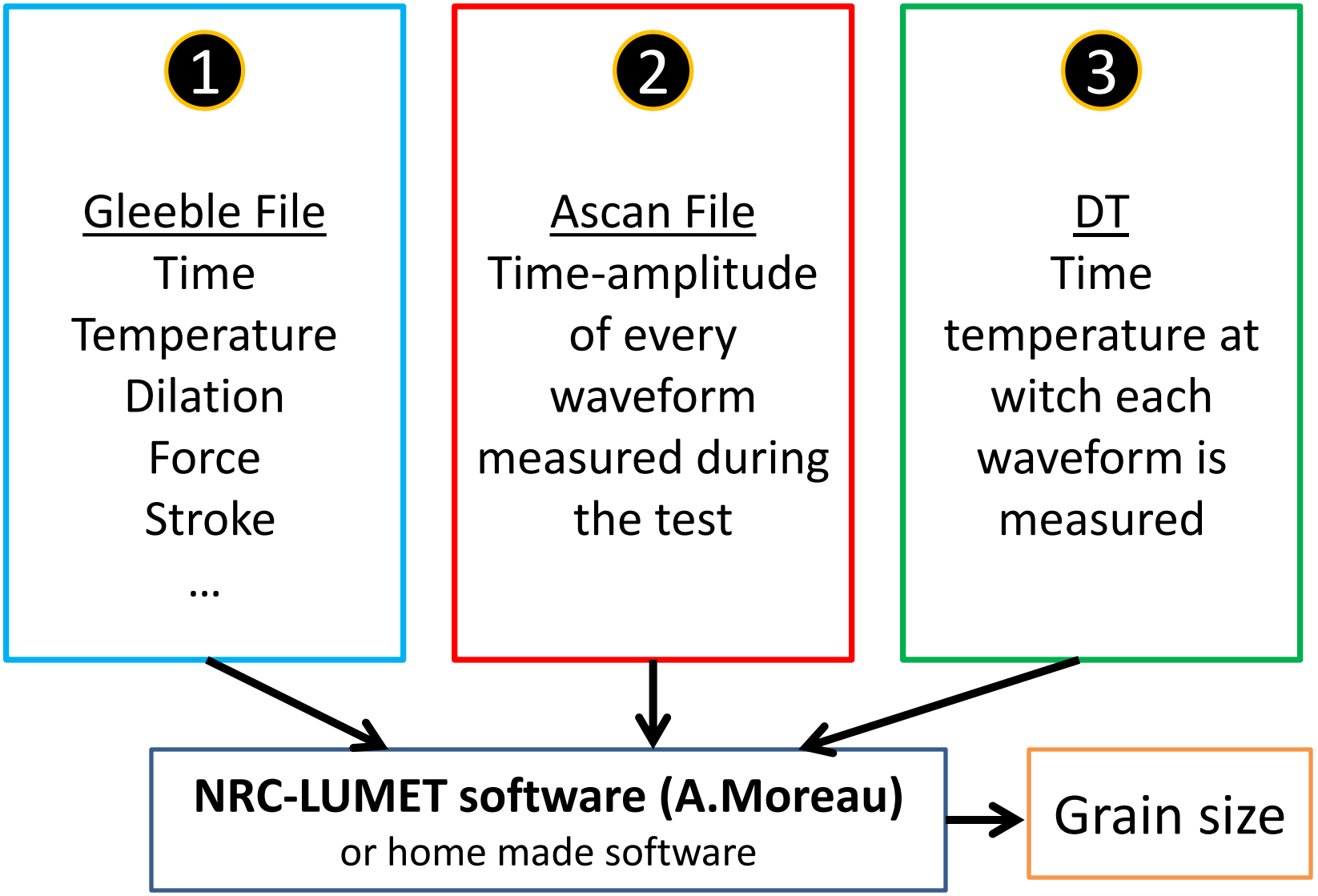


Material and experiment

- ✓ X80 linepipe steel, 100°C/s, 1150°C, 15 min



raw data

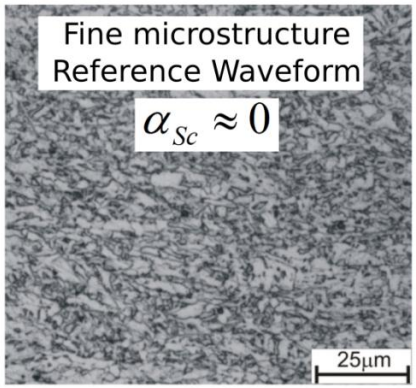

1
Gleeble File
Time
Temperature
Dilation
Force
Stroke
…
2
Ascan File
Time-amplitude of every waveform measured during the test
3
DT
Time temperature at witch each waveform is measured
NRC-LUMET software (A.Moreau)
or home made software
Grain size

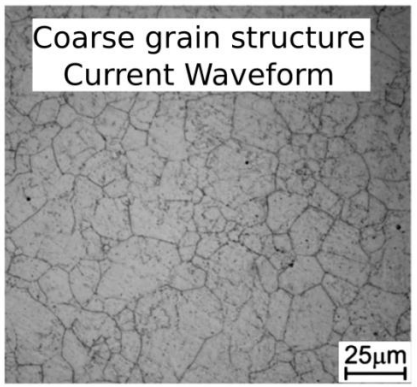
Methodology

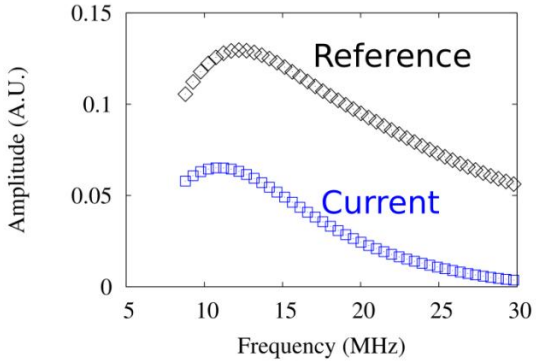
- ✓ Attenuation spectrum from single echo technique

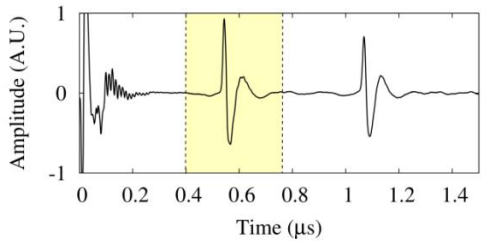
$$\alpha = \alpha_D + \alpha_{Sc}$$

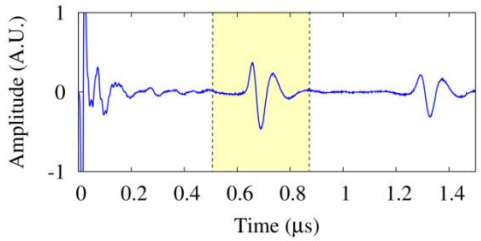
$$\alpha_{Sc} = \frac{20}{2e}\log\left(\frac{A_{Current}}{A_{Reference}}\right)$$

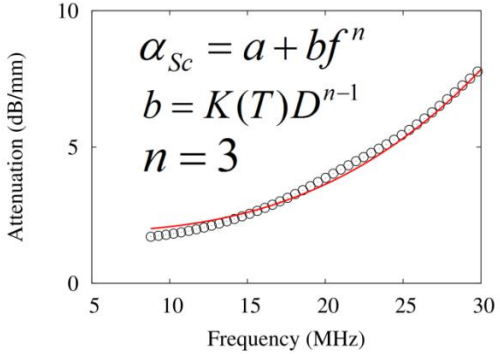








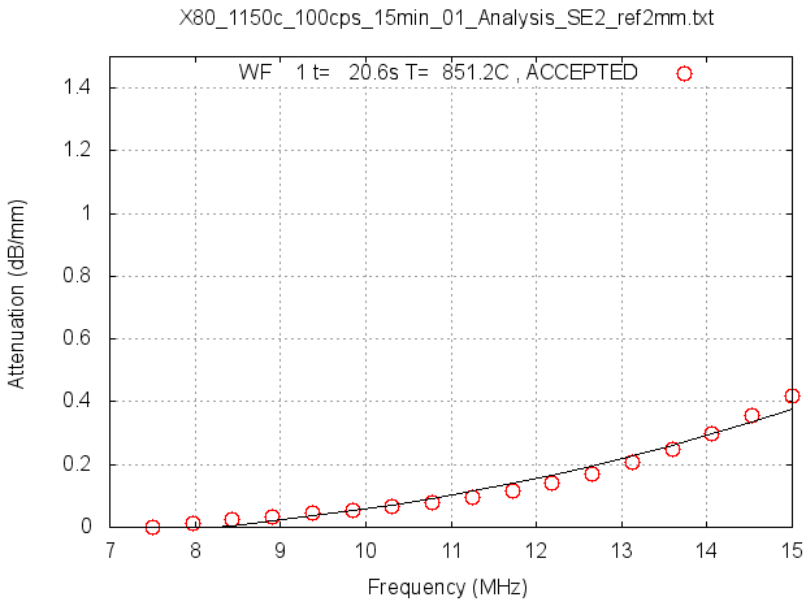


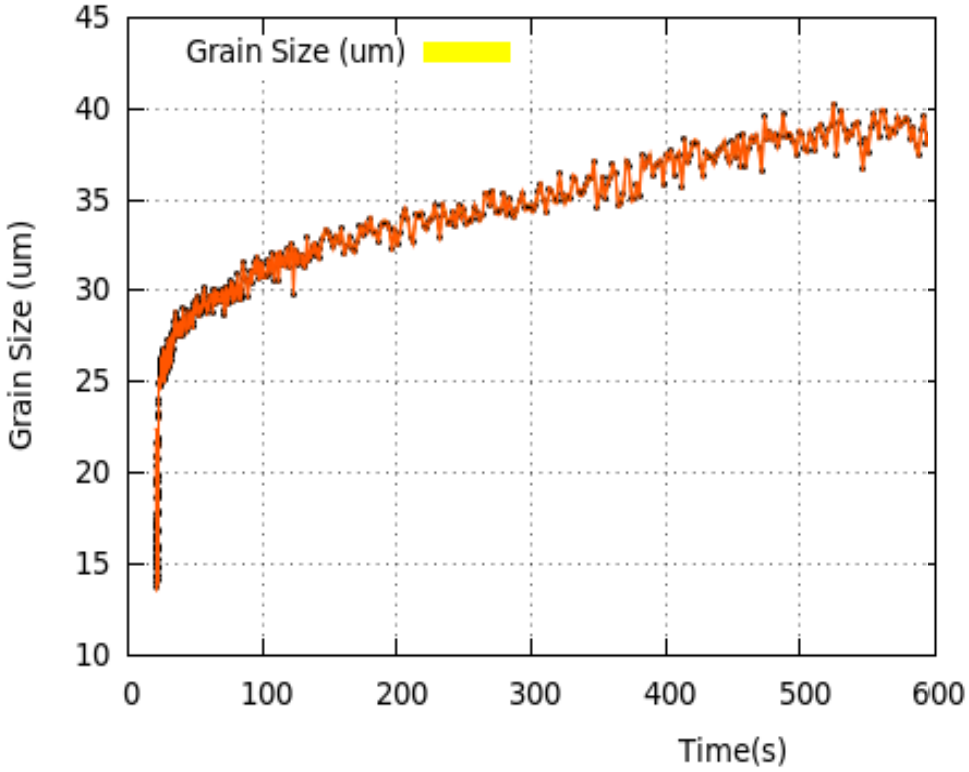


- ✓ Calibration available for austenite in low alloy steel : S.E. Kruger et al., Iron Steel Technol, (2005), 2(10),25

Grain size parameter

- ✓ Regression on attenuation spectrum
- ✓ Evaluation of grain size from available calibration data





Important points

- ✓ Design sample geometry to measure echo in the near or far field
- ✓ Reference sample with weak attenuation (small grains)
- ✓ Use or design a calibration to relate ultrasound parameter to mean grain size