SINUMERIK Edge
Pore Detection

How a world record helps

June 2024

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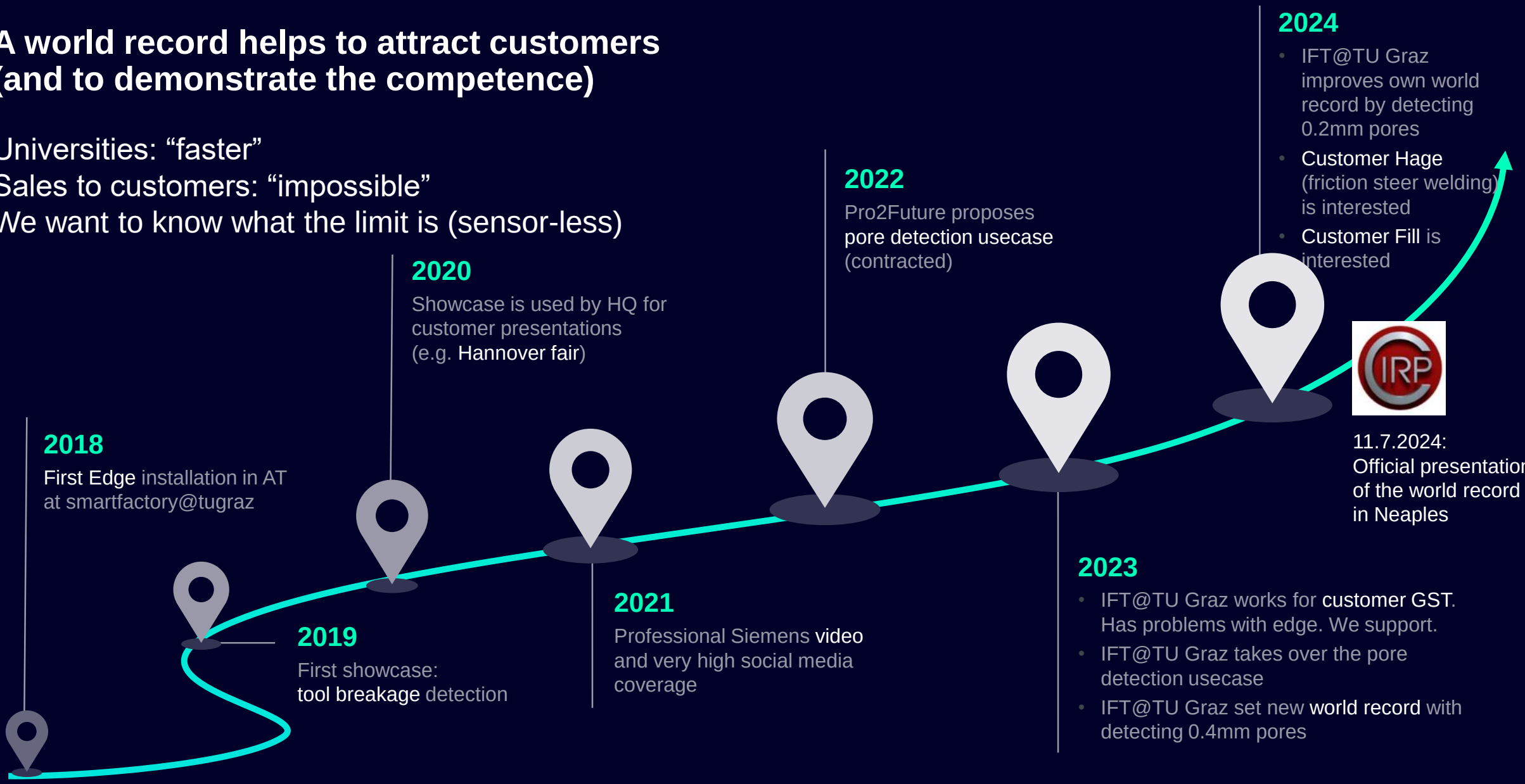
A world record helps to attract customers (and to demonstrate the competence)

Universities: “faster”
Sales to customers: “impossible”
We want to know what the limit is (sensor-less)



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First showcase: tool breakage detection

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Showcase is used by HQ for customer presentations (e.g. Hannover fair)

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Professional Siemens video and very high social media coverage

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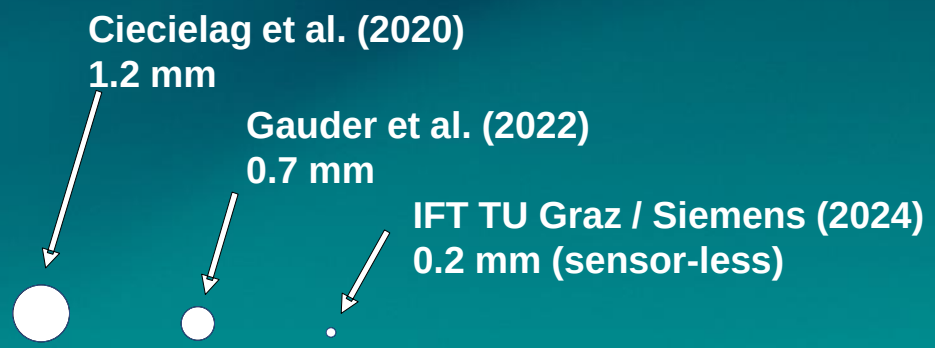
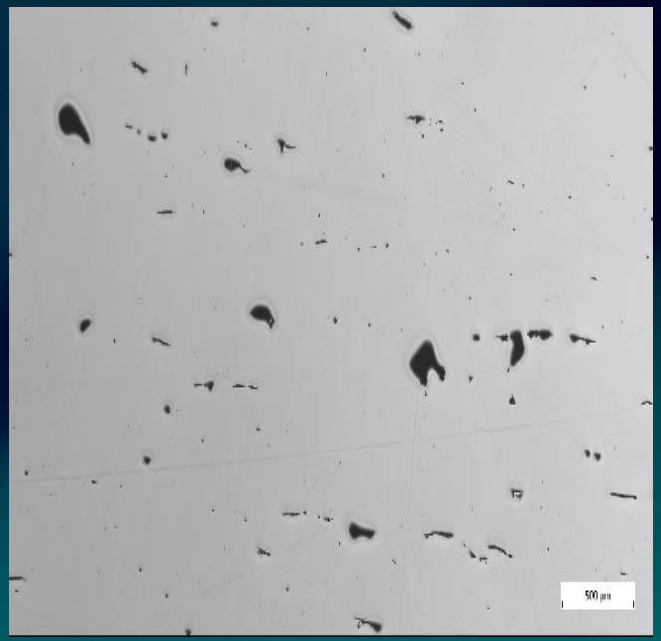
Challenge

How to measure sensor-less a very short event (120µs) with a sampling time of 2ms?





Small cavities or cracks in the raw material

V_c=100m/min (n= 2652rpm), D=12mm, z=4, d=0.2mm, t_d=120µs, f_z=56µm, T_d=20.2ms, T_{rot}=22.62ms=188 t_d

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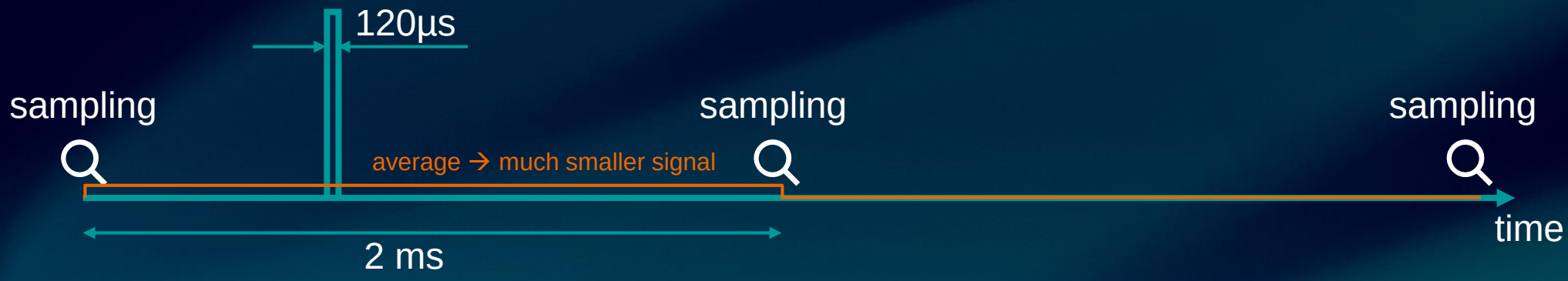
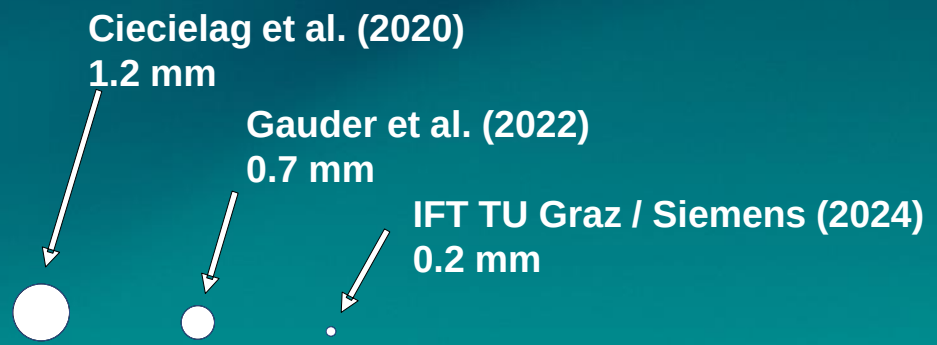
Measuring a very short event with a low sampling rate is only possible, if the event is made larger (e.g. by averaging it at least for one sampling period)





Better:
Averaging over
one full rotation
of the milling tool
(22.62 ms)

V_c=100m/min (n= 2652rpm), D=12mm, z=4, d=0.2mm, t_d=120µs, f_z=56µm, T_d=20.2ms, T_{rot}=22.62ms=188 t_d

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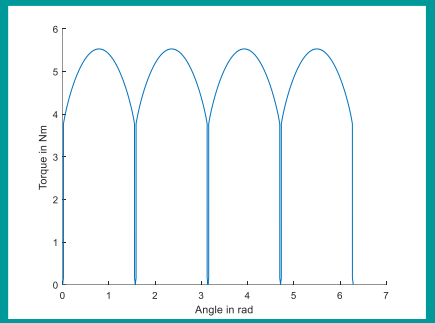
All graphs on this page are perfectly noise-free signal simulations

The truth of the spindle torque over 1 rotation (2π)



KISTLER
measure. analyze. innovate.

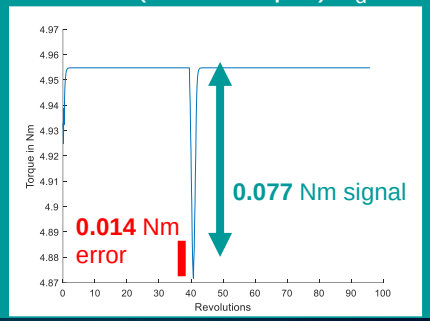
Torque measurement system:
costs >20k€

Perfect average over one full rotation:

Without pore:	4.958 Nm
With 0.2mm Ø pore:	4.881 Nm
Measured signal ΔM =	**0.077** Nm

With sampling-synchronous[2] rotation speed n=2500rpm

V_c=94m/min (n= 2500rpm), t_d=127µs, T_d=21.4ms, T_{rot}=24ms



SINAMICS p0045 = τ = 6 ms (changed)

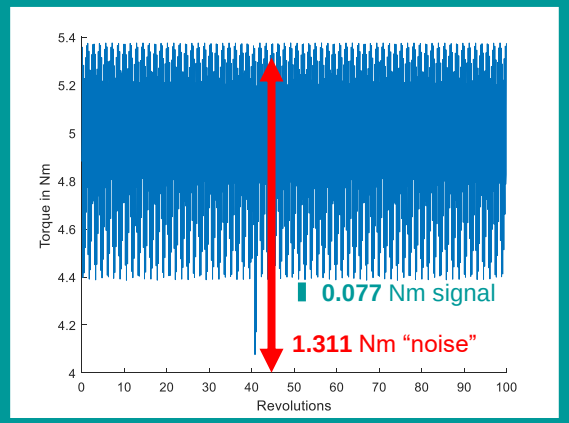
Pseudo-noise amplitude:	0.000 Nm
Error of average:	0,014 Nm

→ Desired feature:
perfect average over one full rotation (instead of low pass filter)
Pseudo-noise amplitude: **0.000** Nm

V_c=100m/min (n= 2652rpm), D=12mm, z=4, d=0.2mm, t_d=120µs, f_z=56µm, T_d=20.2ms, T_{rot}=22.62ms:

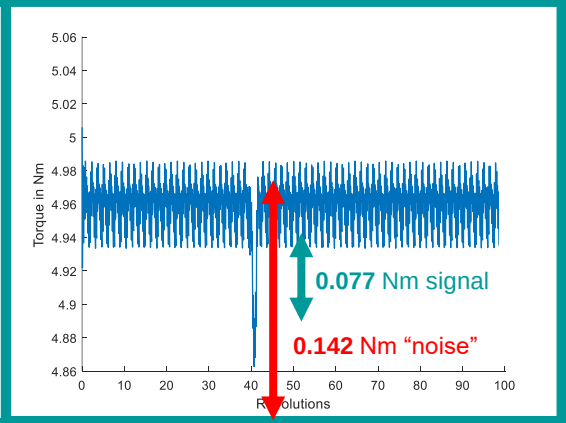
SINAMICS p0045 = τ = 1 ms (default)

Pure signal without moving average[1]



Pseudo-noise amplitude of the pore signal: **1.311** Nm

Signal with moving average[1]:



Pseudo-noise amplitude of the pore signal: **0.142** Nm

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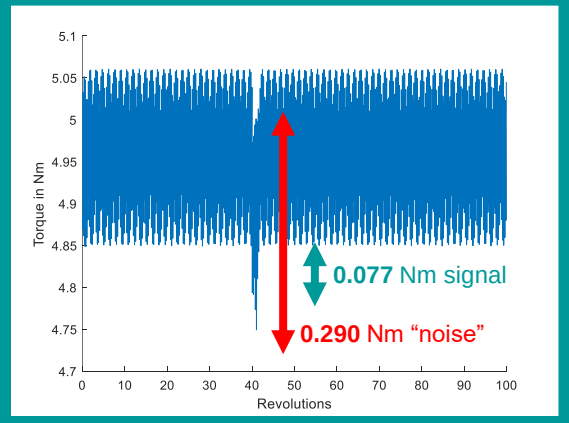
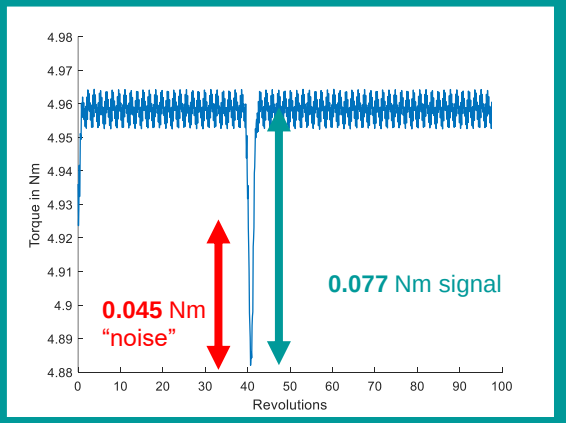


Pseudo-noise amplitude of the pore signal: **0.290** Nm

Signal with moving average[1]:



Pseudo-noise amplitude of the pore signal: **0.045** Nm

1) All time series data are based on perfectly noise-free signal simulations

2) Due to the control activities the rotation speed is in reality never perfectly constant. Therefore the desired feature is required

Real (noisy) measurement with sampling-asynchromous rotation speed n = 2652 rpm

V_c=100m/min (n= 2652rpm), D=12mm, z=4, d=0.2mm, t_d=120µs, f_z=56µm, T_d=20.2ms, T_{rot}=22.62ms:

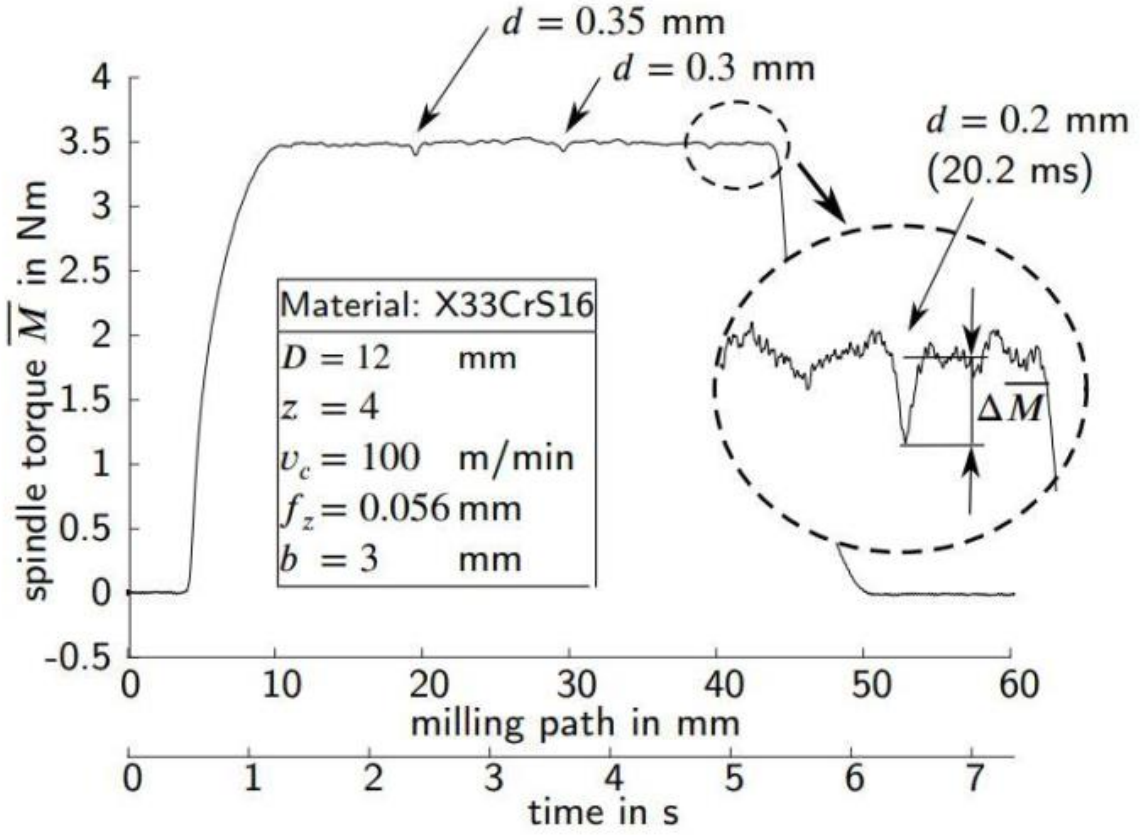
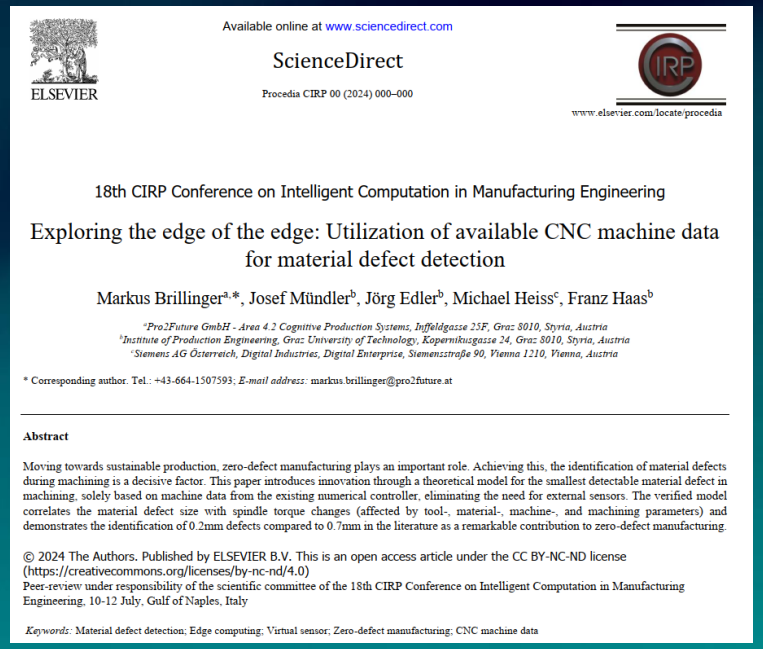


Fig. 4. Spindle torque $\overline{M}$ during groove milling with small material defects (air pores) diameters d at the milling path positions 20 mm, 30 mm, and 40 mm. In this setting, $d$min = 0.2 mm air pores are the limit for being robustly detected.



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18th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Exploring the edge of the edge: Utilization of available CNC machine data for material defect detection

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Abstract

Moving towards sustainable production, zero-defect manufacturing plays an important role. Achieving this, the identification of material defects during machining is a decisive factor. This paper introduces innovation through a theoretical model for the smallest detectable material defect in machining, solely based on machine data from the existing numerical controller, eliminating the need for external sensors. The verified model correlates the material defect size with spindle torque changes (affected by tool-, material-, machine-, and machining parameters) and demonstrates the identification of 0.2mm defects compared to 0.7mm in the literature as a remarkable contribution to zero-defect manufacturing.

Peer-review under responsibility of the scientific committee of the 18th CIRP Conference on Intelligent Computation in Manufacturing Engineering, 10-12 July, Gulf of Naples, Italy

Keywords: Material defect detection; Edge computing; Virtual sensor; Zero-defect manufacturing; CNC machine data

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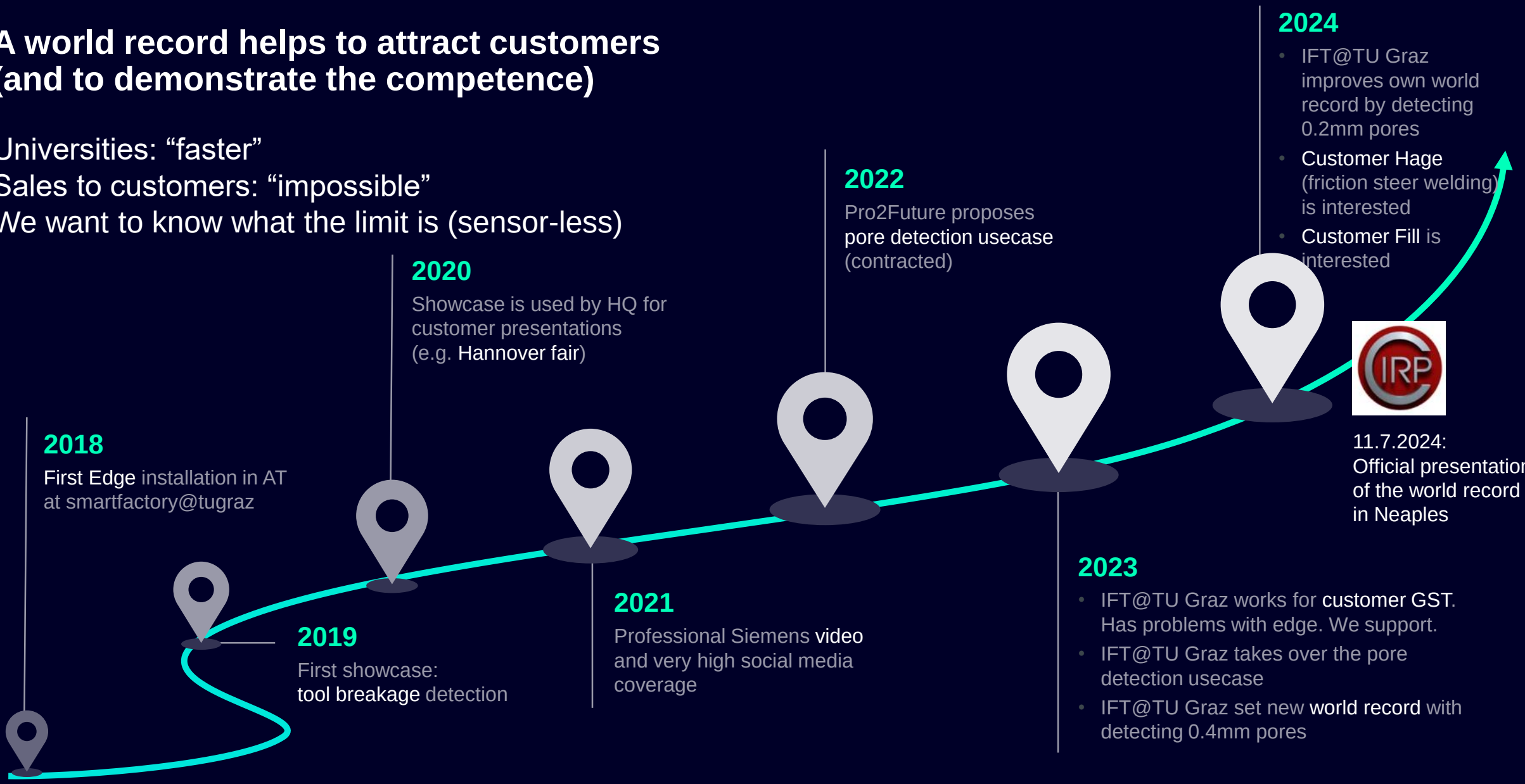

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Backup

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Sampling Theory / “Shannon Theorem”

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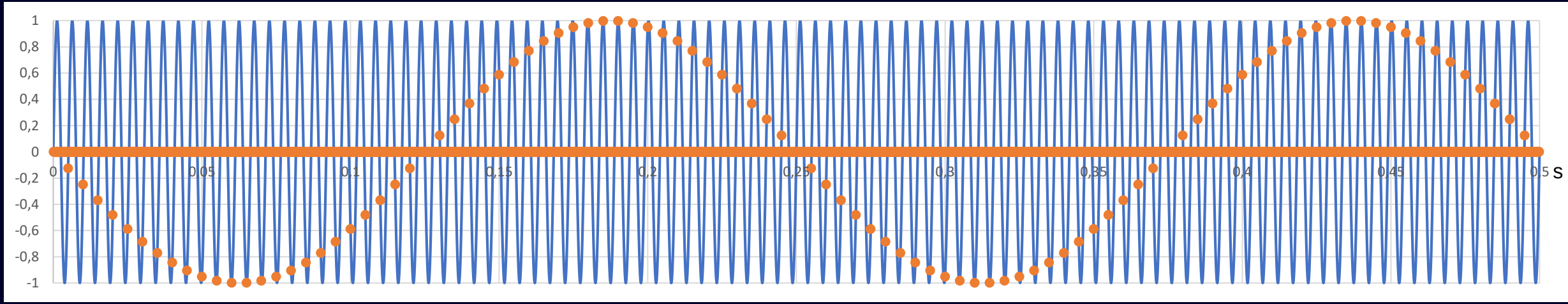
What do you see?



a sampled ~~4Hz~~ sinus signal

Truth: a 196Hz sinus signal, sampled with 200Hz

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