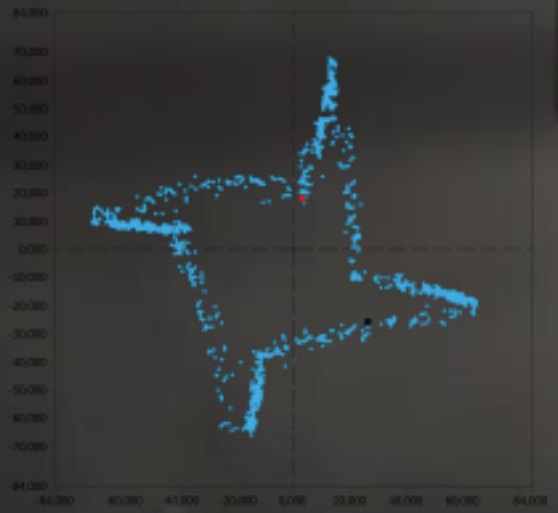
spike®

promicron wireless solutions

spike®

CONTROL THE FORCE



measures cutting forces…

- *directly on the tool*
- *visualizes each cutting edge*
- *transfers data wirelessly*

- *in 24/7 h line production and R&D*
- *visualize - diagnose – monitor – control*

- *Intelligent tool & smart data management & machine learning*

*In order to set a standard in **digital machining** over the whole value chain!*

Frequently asked questions

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Tool Manufacturers & Tool Holder Manufactures

How do you prove the quality/performance of your tools?

How will the cutting force change if I change the tool angle ?

How long do I need to do my test trials?
How do I analyze my test trials?

How can I help the customer to solve process problems in production faster?

What can I do in order to give a whole solution and not just tools to the customer?

Component Manufacturers

When should I change my tool ?

Am I using the tool to its full capacity ?

Digital machining?

Which tool should I buy ?

How do I guarantee 100% quality?
- shape and position tolerances?
- surface quality?

How fast is my machine to detect problems before they happen?

I already have monitoring systems but how can I monitor the critical, more sensitive processes?

Machine Tool Manufacturers

How can I help my customer to achieve work piece quality ?

Why is one machine more productive than the other ?

Institutes & Universities

What should modern machining be able to do tomorrow?

Quality control with spike_easyinline through spike_kpi

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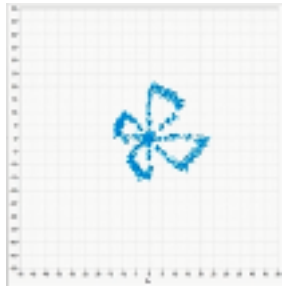
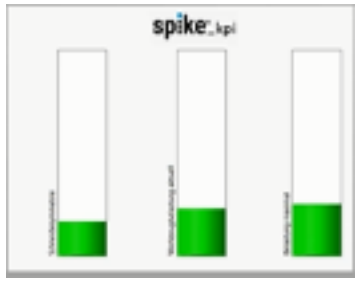
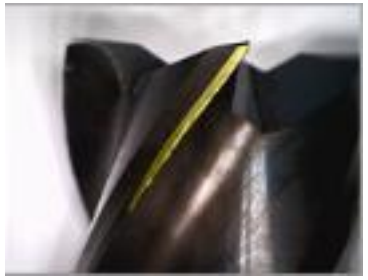
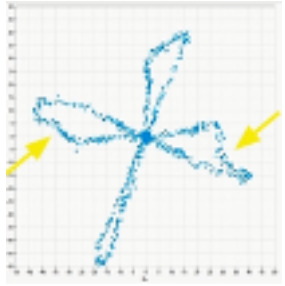
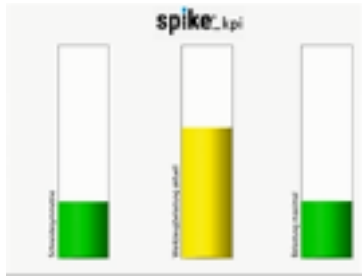
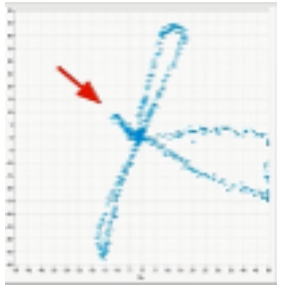
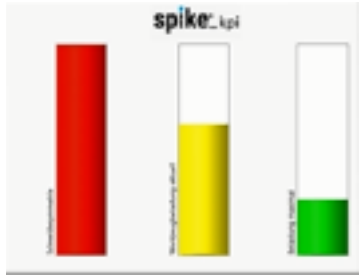
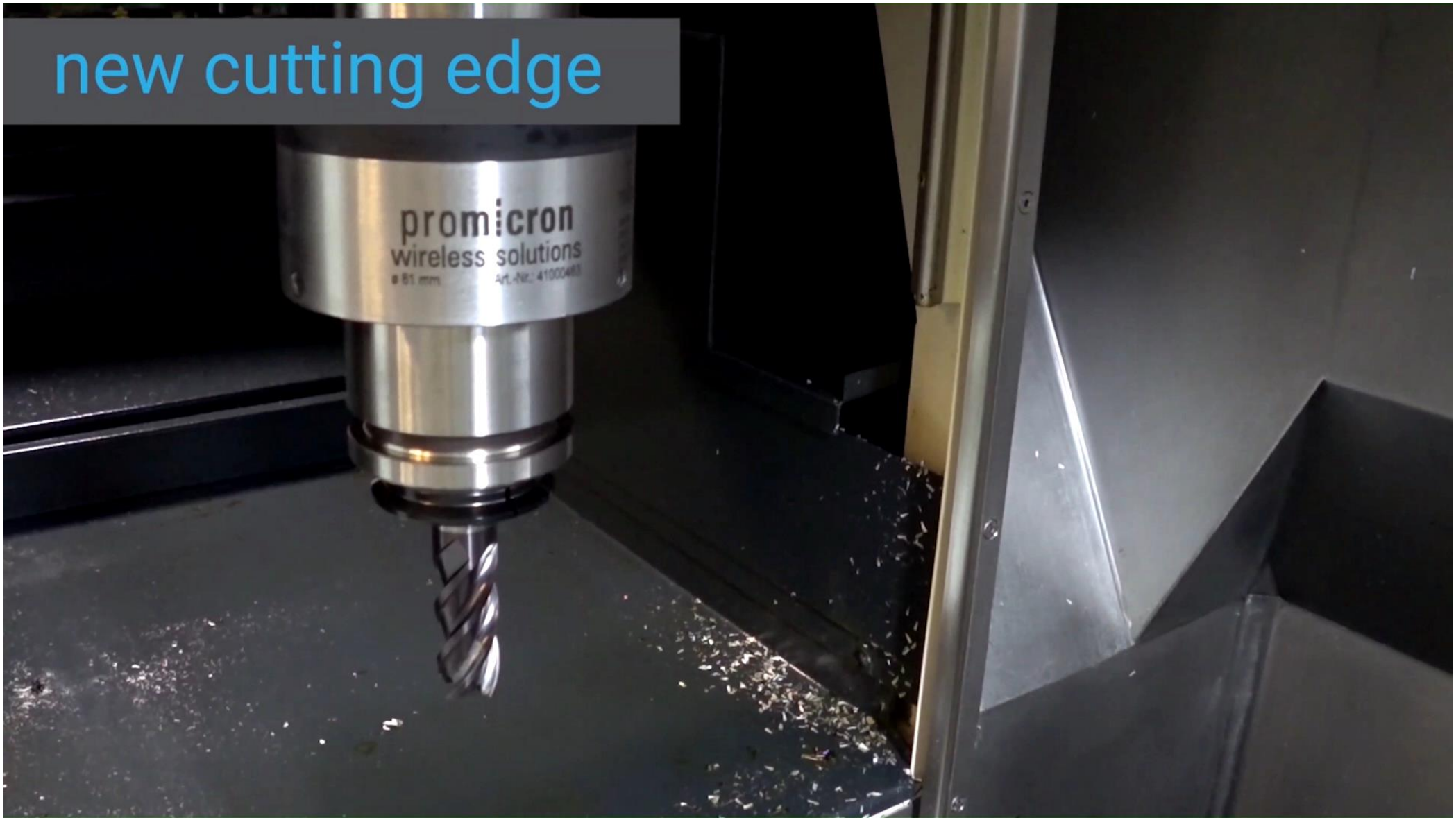
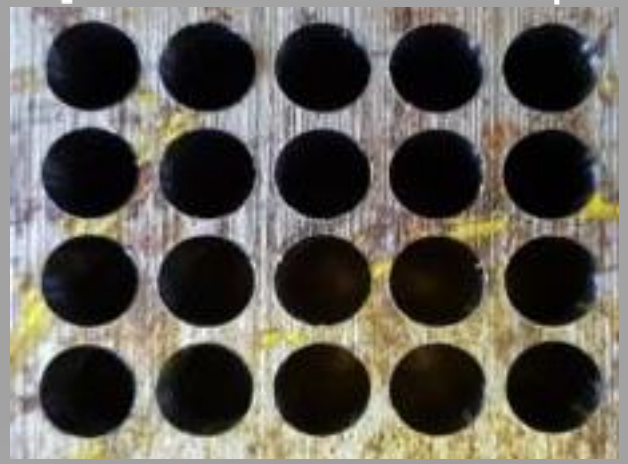
state	work piece	tool		spike_polar	spike_kpi
new					
worn					
cutting breakage					

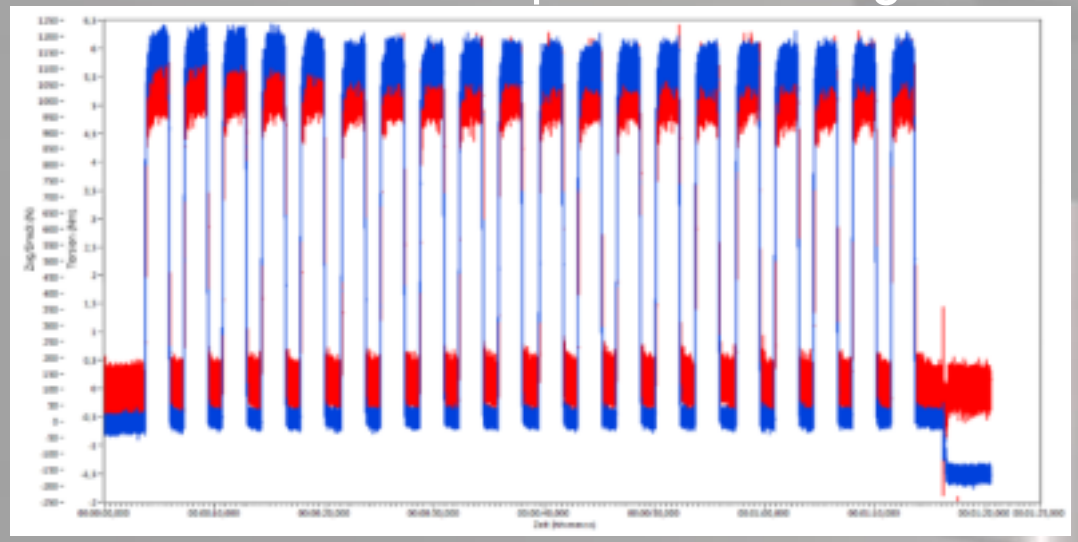
Quality control with spike_easyinline through spike_kpi



Monitor shape and form tolerances via spike® bending moment



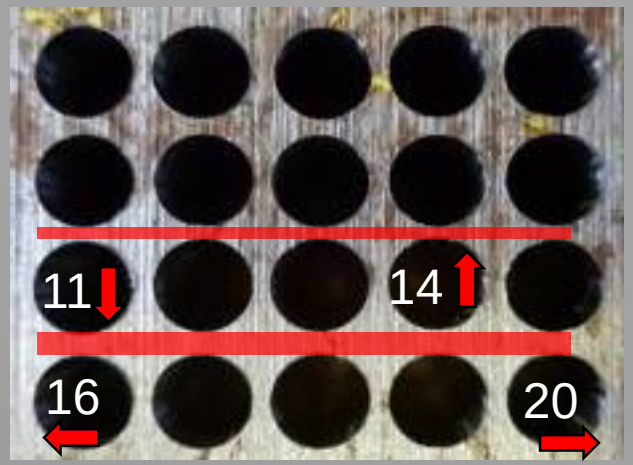
Drill entry



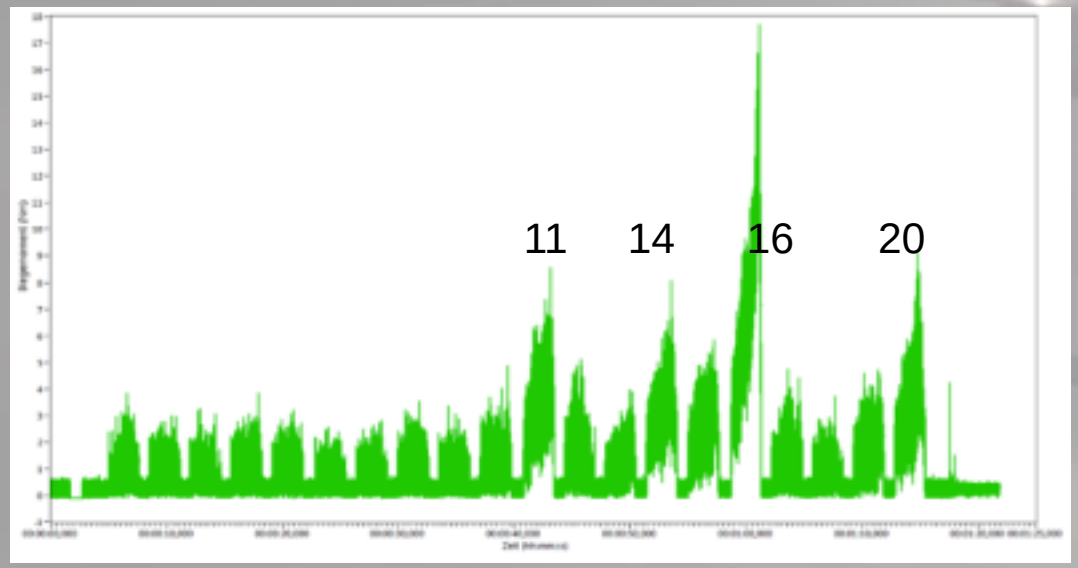
pressure

torsion

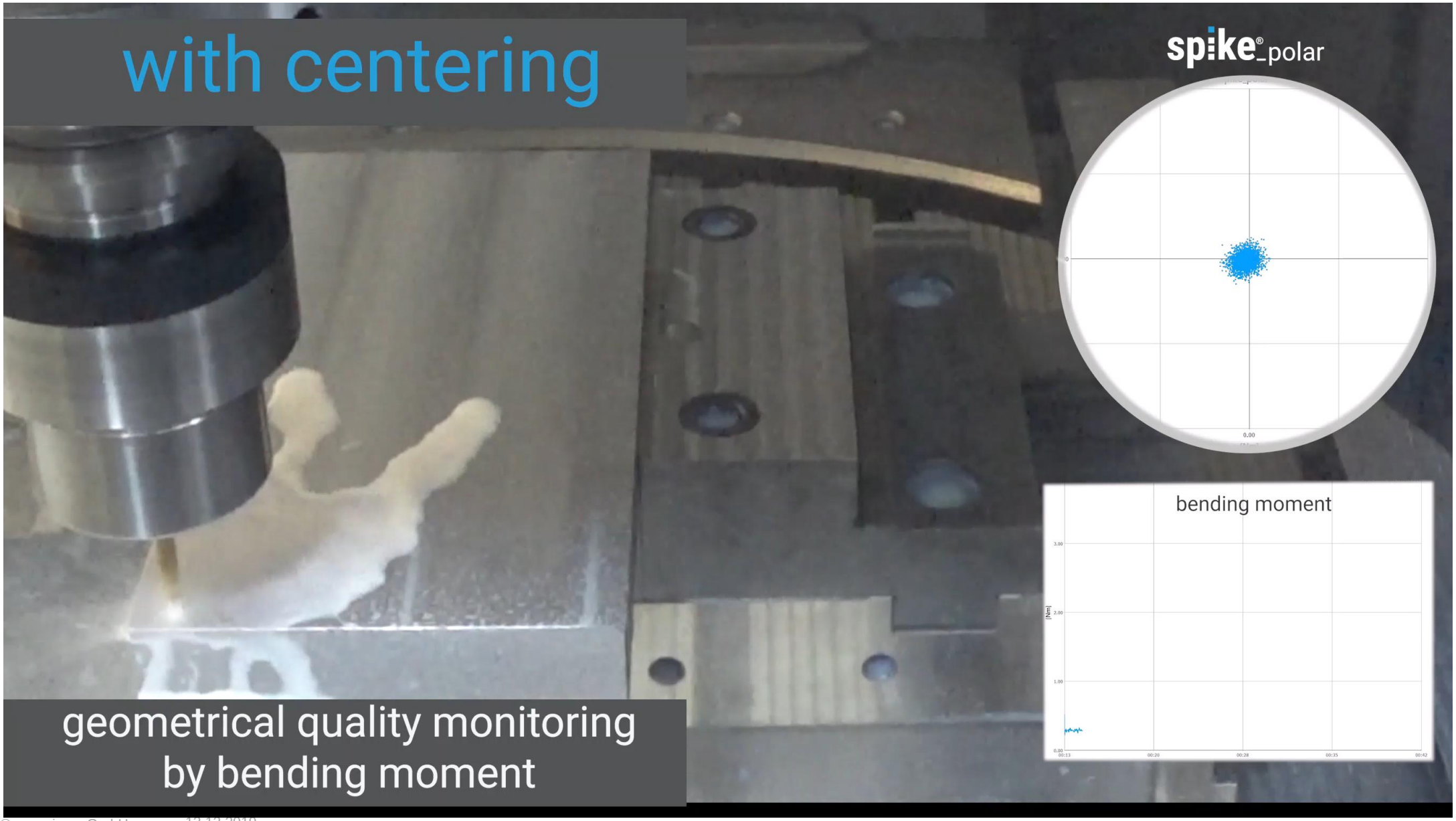
bending moment



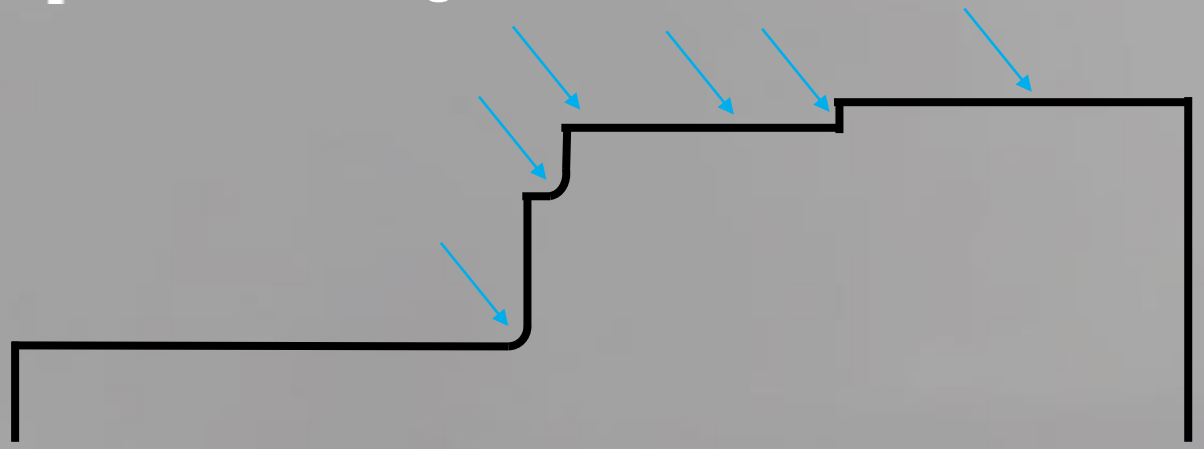
Drill exit

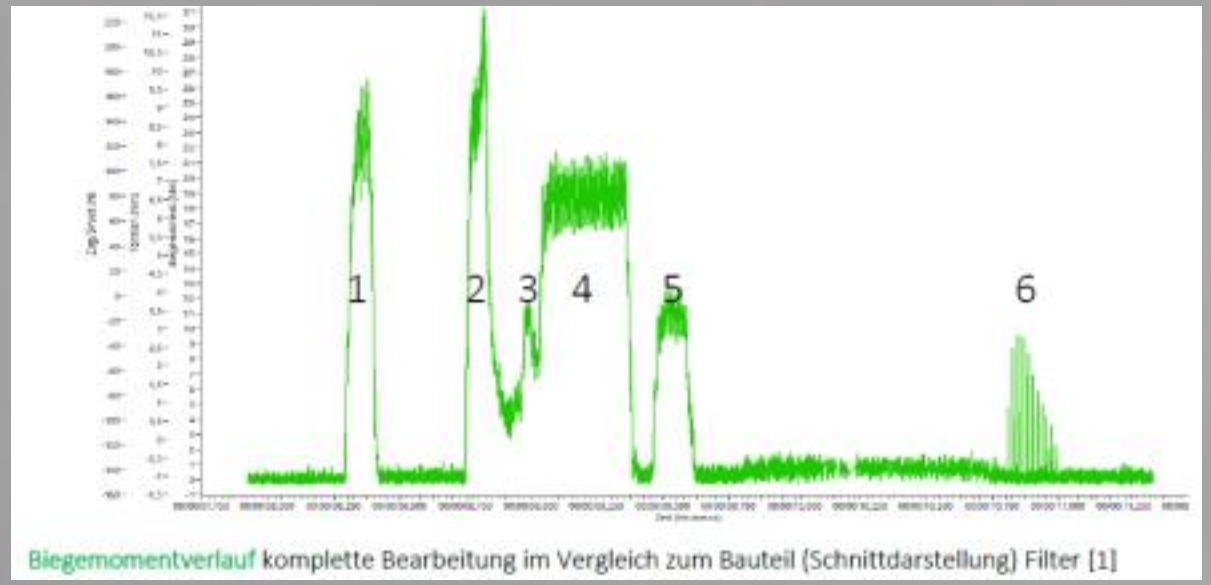


Example – Detection with centering



spike® Turning – monitor tolerances



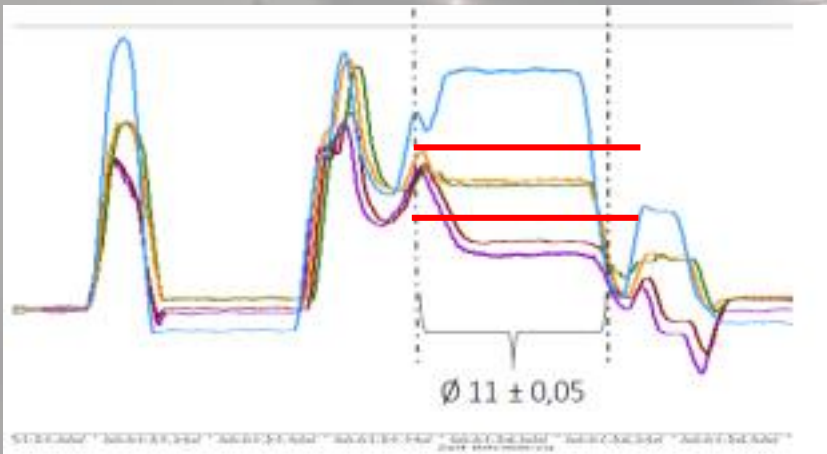


Biegemomentverlauf komplette Bearbeitung im Vergleich zum Bauteil (Schnittdarstellung) Filter [1]

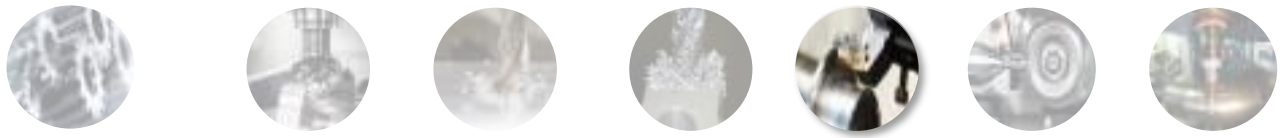
Platte 1 (links) - NEU

Platte 2 (rechts) – Verschlissen

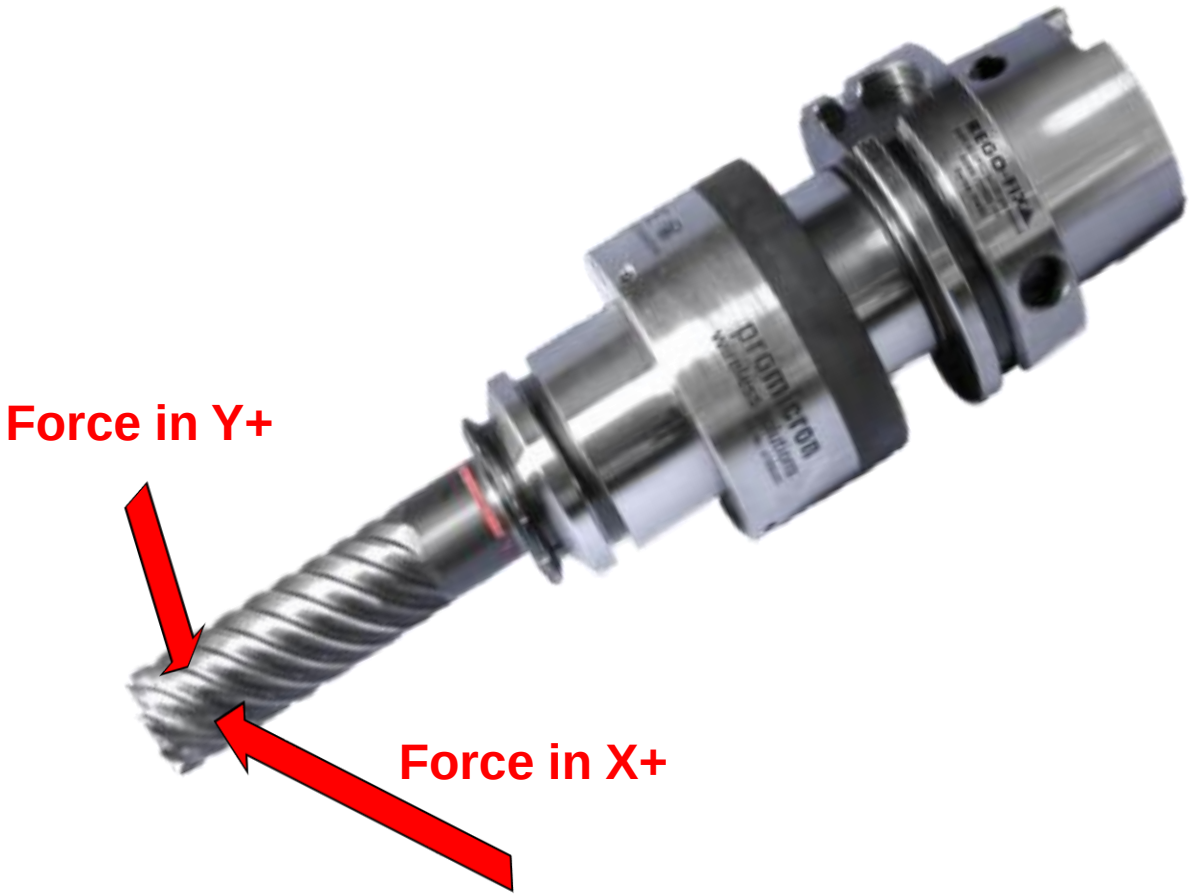
Name	Ist Maß Ø 11 ± 0,05	Sonstiges
Teil 1:	10,5484	Einfahrteil
Teil 2:	11,0021	1. Bauteil nach Radiuskorrektur (Platte 1 - NEU)
Teil 3:	11,0006	2. Bauteil nach Radiuskorrektur (Platte 1 - NEU)
Teil 4:	11,1023	1. Bauteil mit verschlissener Platte (Platte 2 - Verschlissen)
Teil 5:	11,1103	2. Bauteil mit verschlissener Platte (Platte 2 - Verschlissen)

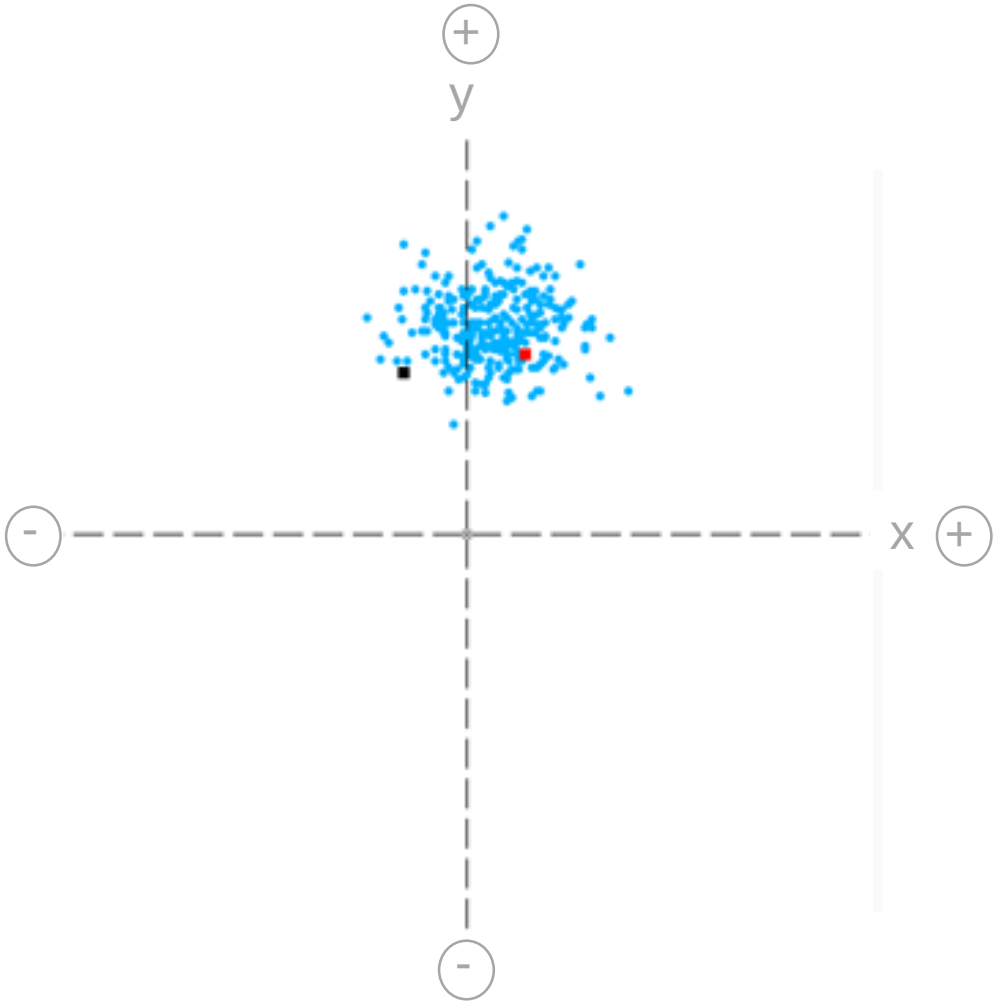


Biegemoment X-Komponente (je kleiner die Kräfte, desto weniger Material wurde abgetragen) Filter [100]



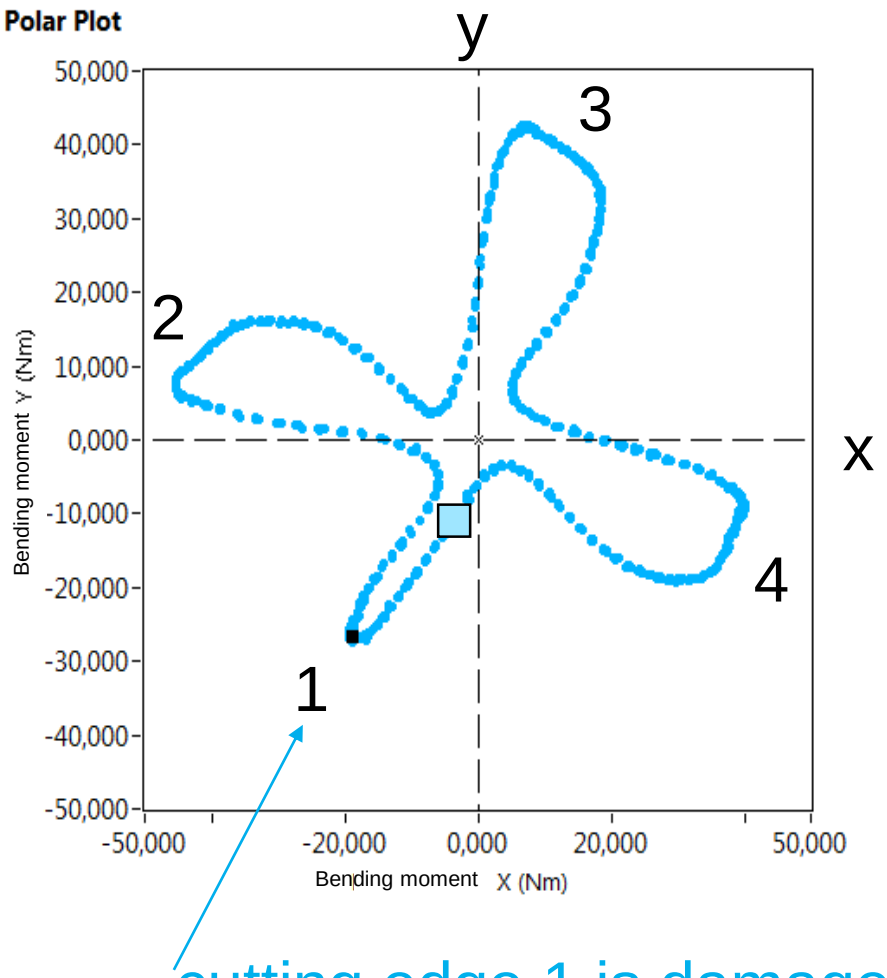
What is the spike®_polar?



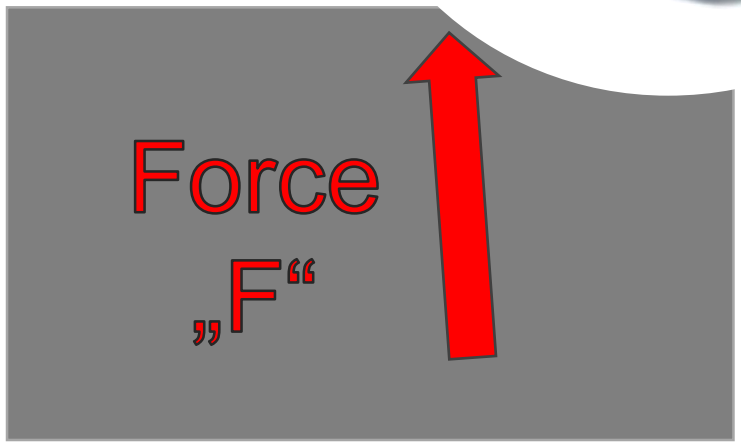


→spike® shows bending moment in tool holder coordinates, NOT in machine / work piece coordinates

What is spike_polar?



cutting edge 1 is damaged



Influences on the spike®_polar design

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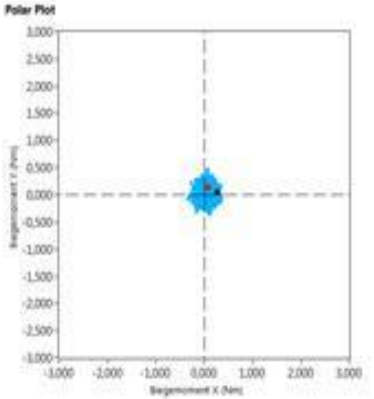
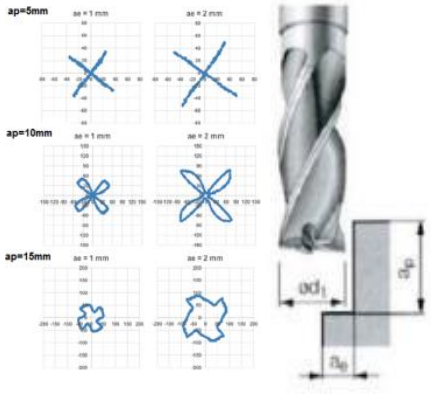
wireless solutions

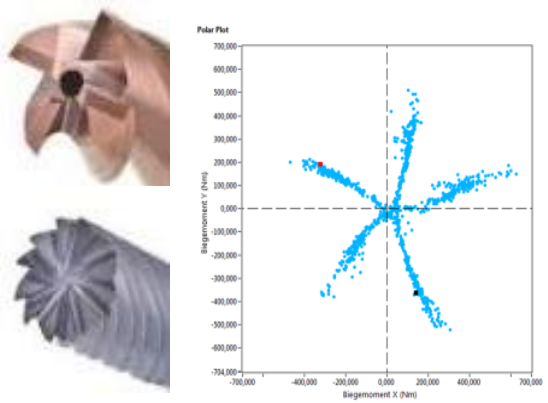
without force



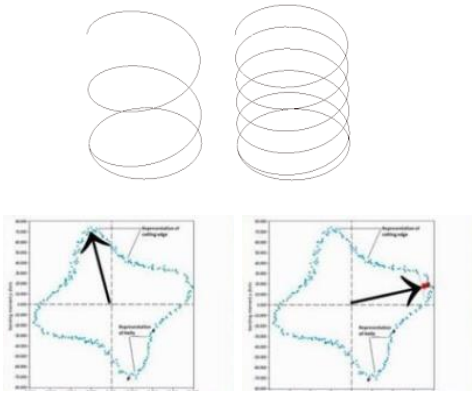
step over (ap/ae)



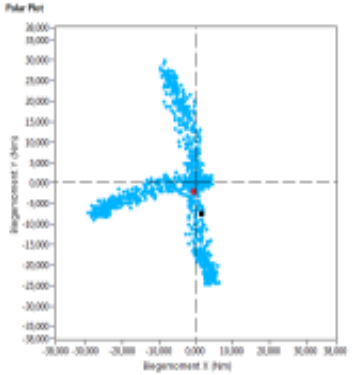
number of cutting edges



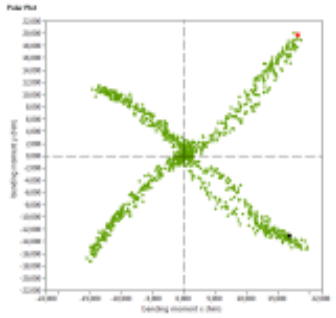
kind of helix



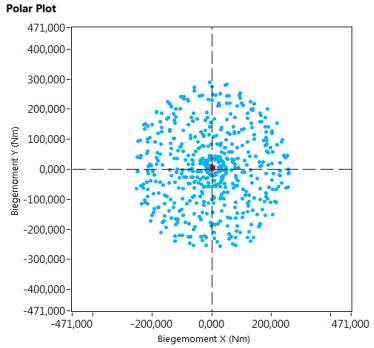
cutting break



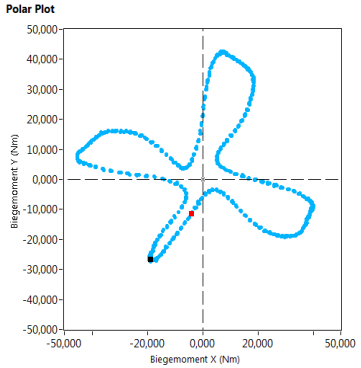
built-up edge



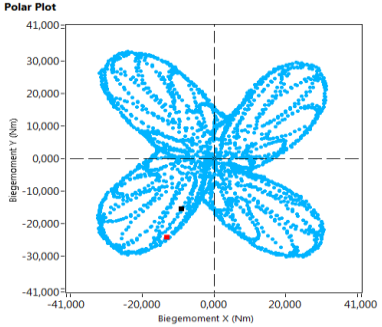
vibration



wear



trochoidal



Measuring Forces and Moments Where They Occur – Close to the Tool

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spike®_mobile

measures directly

- axial force
- torque
- bending moment in x- and y-direction
- (temperature)

spike®_inspindle


Milling


Drilling/ Threading


Turning


Grinding


FSW

Customised solution for your needs

promicron
wireless solutions

Visualisation spike_assist

For application with small and medium batch sizes

UPGRADEABLE

spike _connect_assist ▸ assistance system for machine operator

Benefit: „assistance system“
- visual process support „process status at a glance“
- allows conclusions to be drawn about the relative utilization of the tool holder (%)*
- indirect wear detection (%)*
- manual protection against machine/process overload (%)*

* % of the tool holder strengh

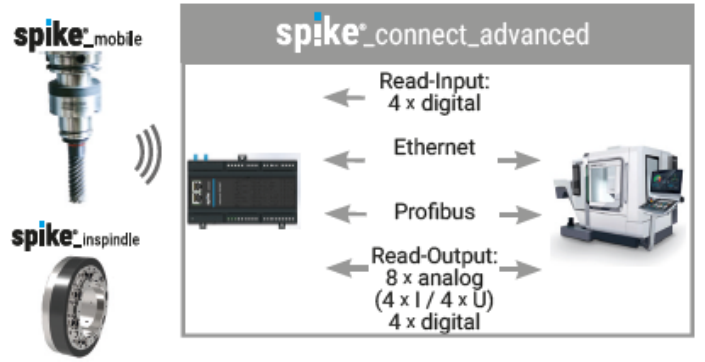
Diagnose spike_expertline

For applications to optimise processes and tools

spike _connect_basic ▸ for flexible use from the trunk

Benefit: „diagnostic system“
- solve process problems faster
- productivity and tool life optimization
- product development and optimization (tool, coating, cooling lubricant, process, machine,...)
- R & D (Institutes & Universities)

Monitoring spike_easyinline



*optional with the assistance system of ToolScope

For applications in automated serial production

spike _connect_advanced ▸ with machine interface

Benefit: „surveillance system“
- 100% in-process quality control
- monitoring of shape and position tolerances (indirect)
- reduction of tool costs (via force-controlled tool change)
- avoidance of machine downtime
- adaptive feed control
- unmanned production

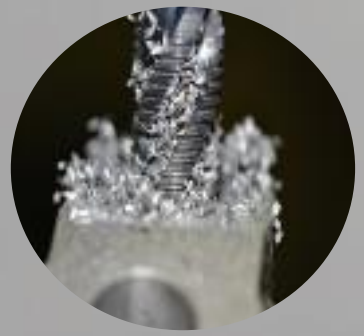
*optional with the assistance system of ToolScope

all views are based on data from the same source

spike® Applikationen

MILLING

DRILLING



THREADING

TURNING

GRINDING

FSW

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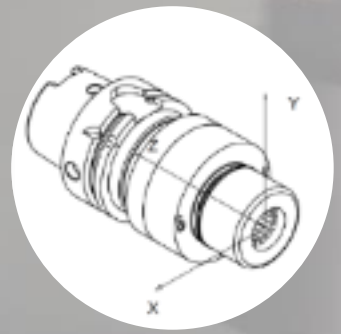
wireless solutions

STRATEGY



CONFIGURATION
spike®_mobile

spike®
data management

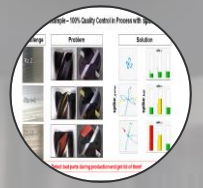
spike®_assist

spike®_ai

spike®_expertline

Amortisation
calculation

spike®_easyinline



spike®_kpi

spike®_Referenzen

4 Messages to Remember

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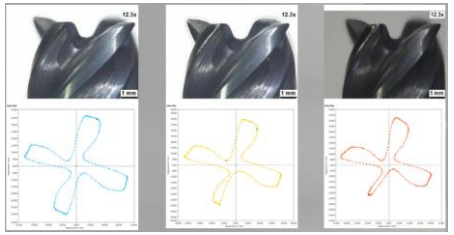
wireless solutions

Function

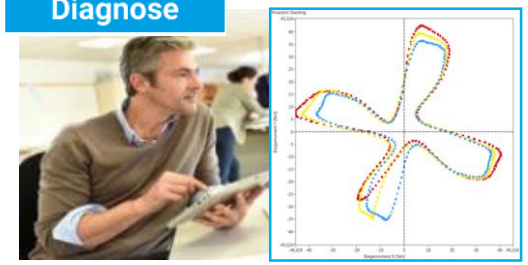
every single cutting edge wireless



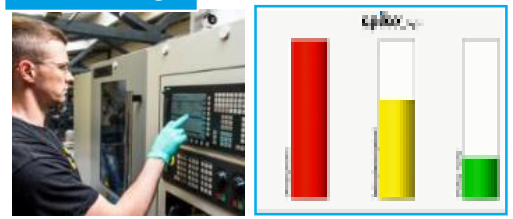
Application

Visualisation

Diagnose



Monitoring

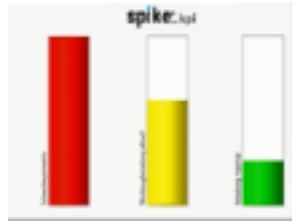


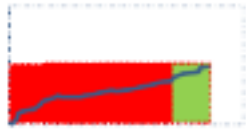
Product Groups

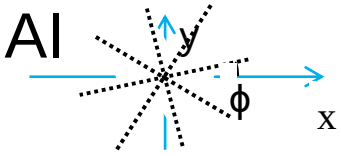
Assistence System (%)

Measurement systems

Strategy



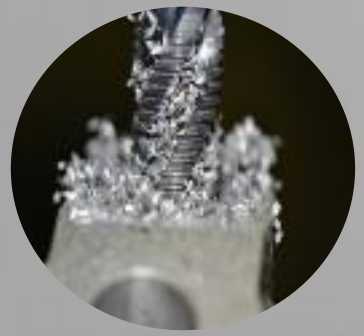




spike® Applications

MILLING

DRILLING



THREADING

TURNING

GRINDING

FSW

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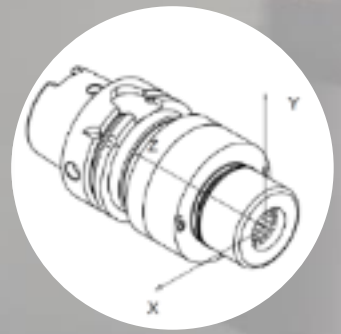
STRATEGY



CONFIGURATION
spike®_mobile

spike®
data management

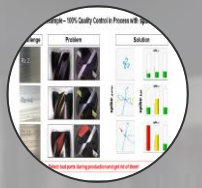
spike®_assist

spike®_ai

spike®_expertline

Amortisation
calculation

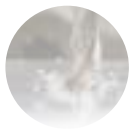
spike®_easyinline



spike®_kpi

spike®_Referenzen







Start

End

MILLING

Influence of Different Deliveries

spike®_polar stacking

Tool Comparison

Face mill insert (bearing)

Tool Comparison 2

Coating Comparison

Extend Tool Life Time

Concentricity Error

Speed Variation

Wear

Wear Rating

Workpiece Positioning

Tool Geometry

Clamping

Trochoidal

Material Test / Maschine Diagnosis

Application in Tool and Mould Construction

Amortization

Skiving

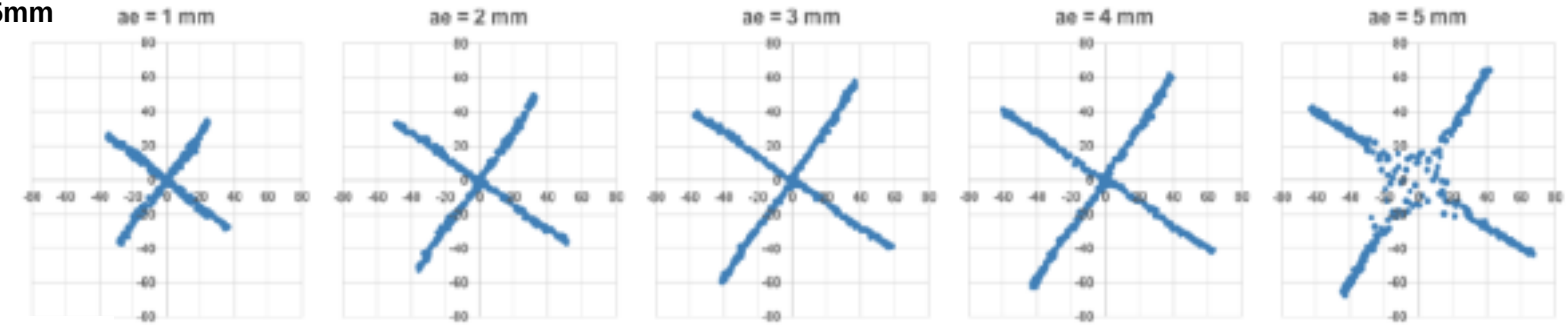
Process Analysis and Monitoringin CFK

spike_kpi´s in Tool

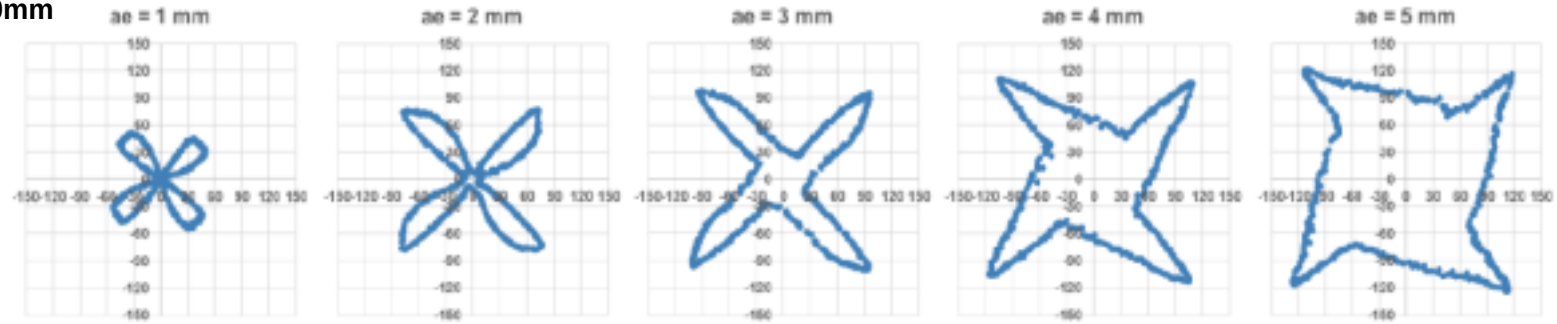
Temperature Control

Milling – Influence of different step overs

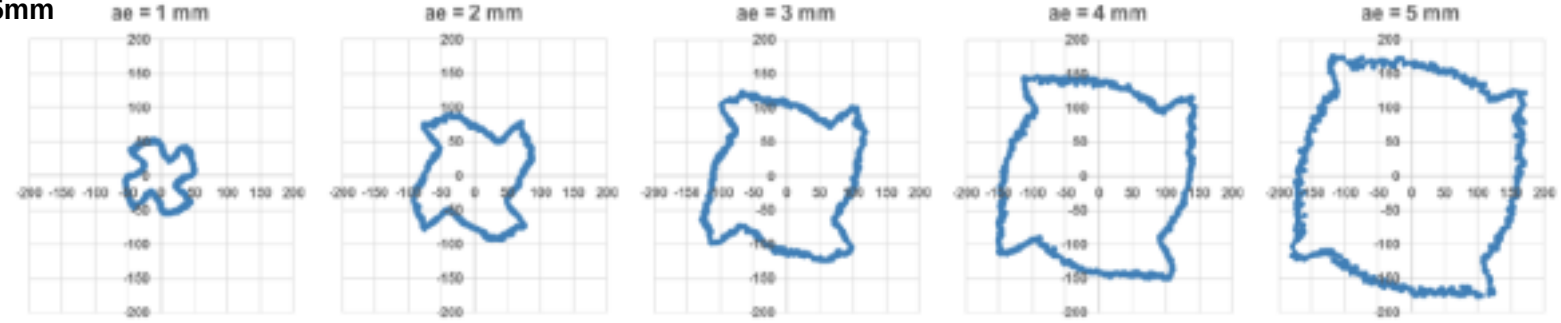
ap=5mm



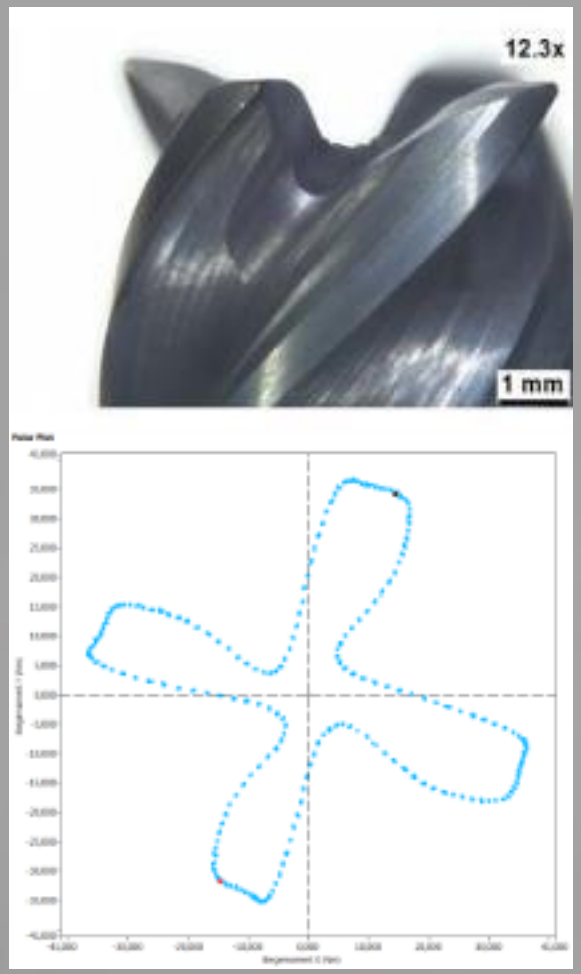
ap=10mm

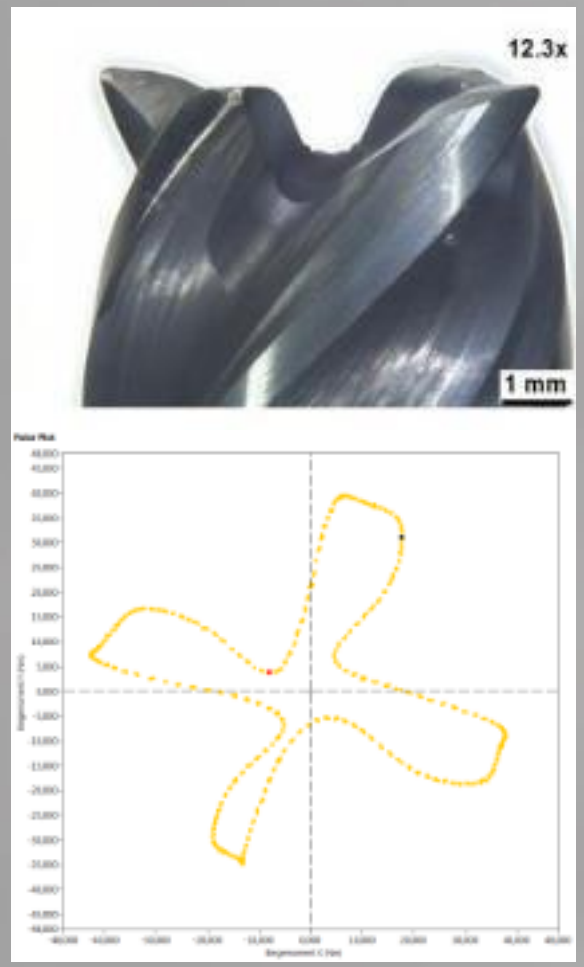


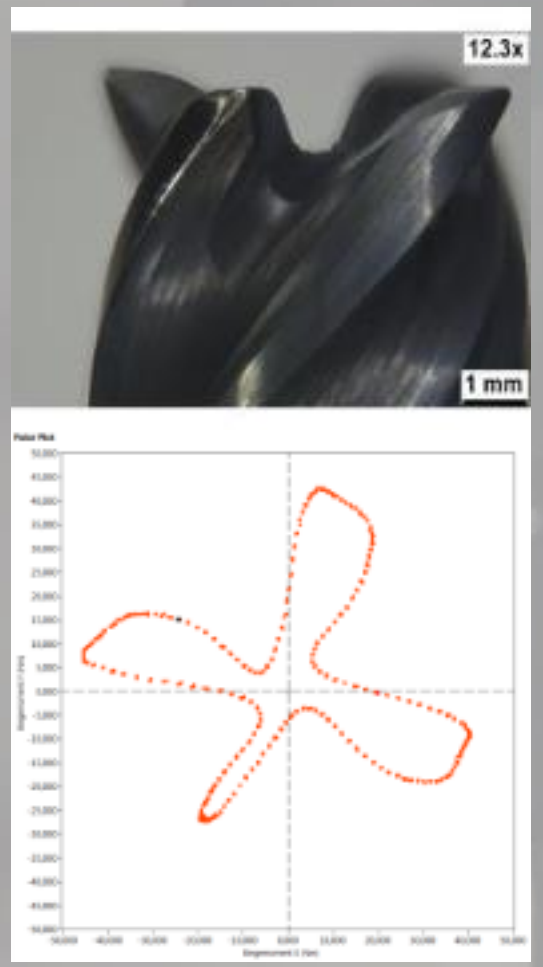
ap=15mm



spike_polar - Cutting edge comparison

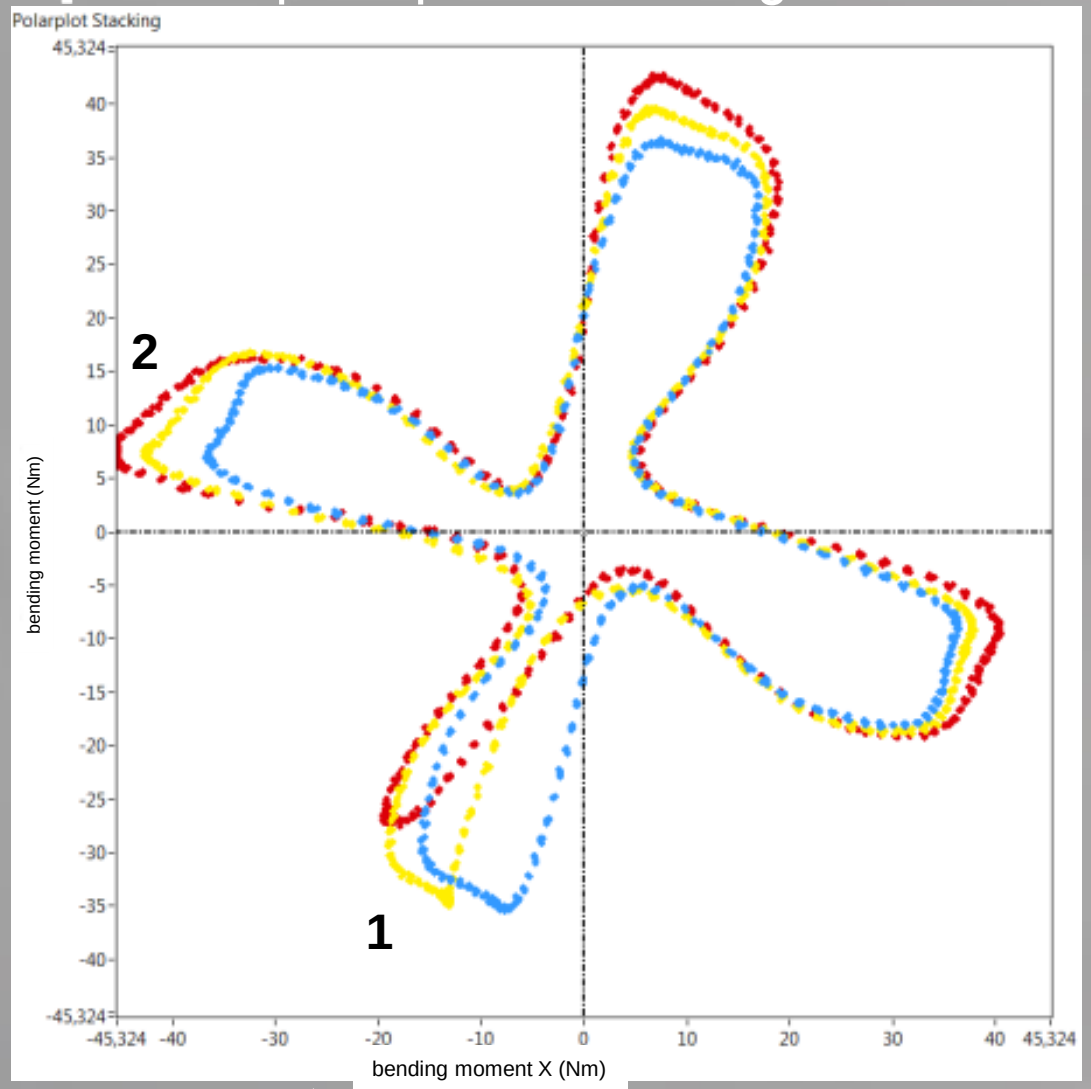




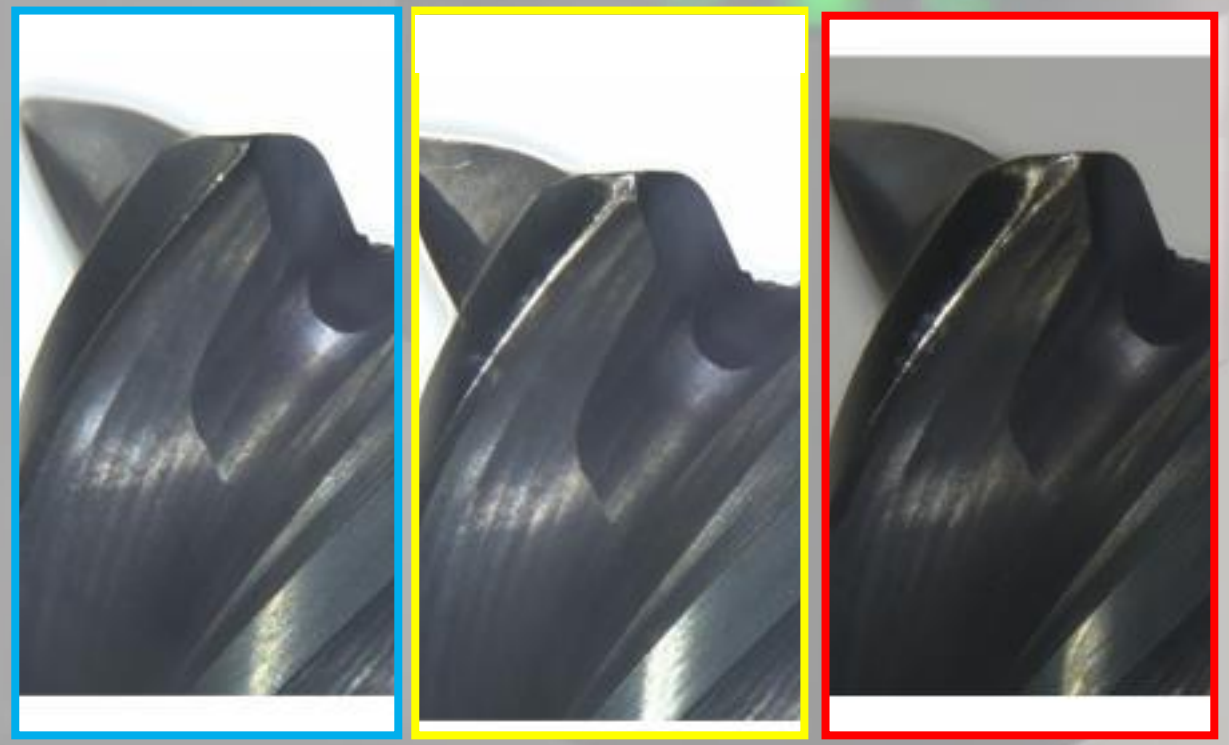


Techn. Data:
Ø= 6
z=4
ap=3mm
ae=1,5mm
vc=191 m/min

spike_polar_stacking

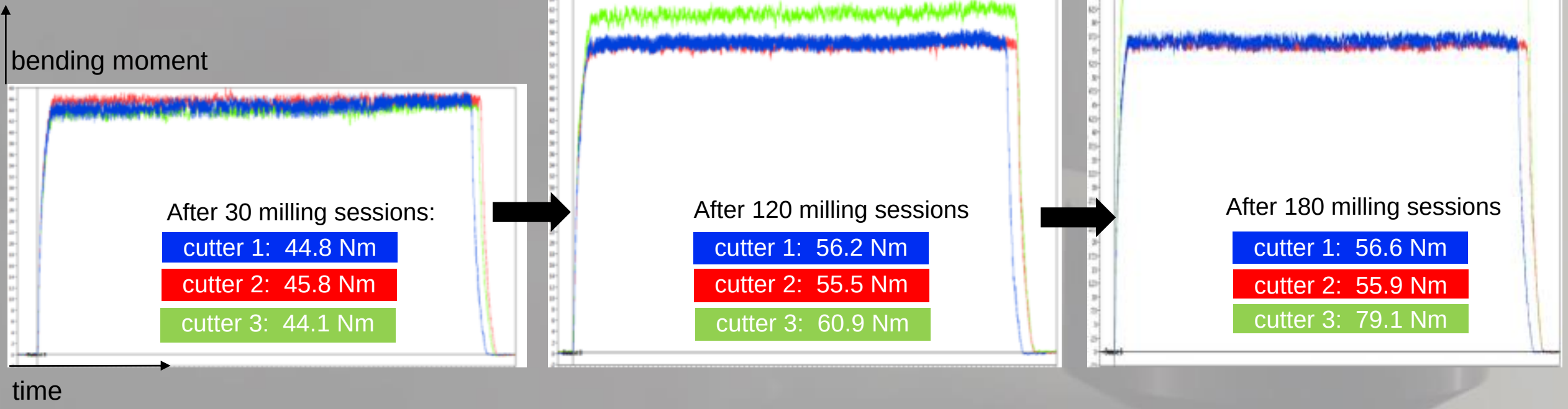


State cutting edge **1**



- Edge 1 artificial worn → later intervention
- Edge 2 needs more power

Tool qualification by bending moment



cutter 1 shows best price-performance ratio because it‘s cheaper than cutter 2 & cutter 3

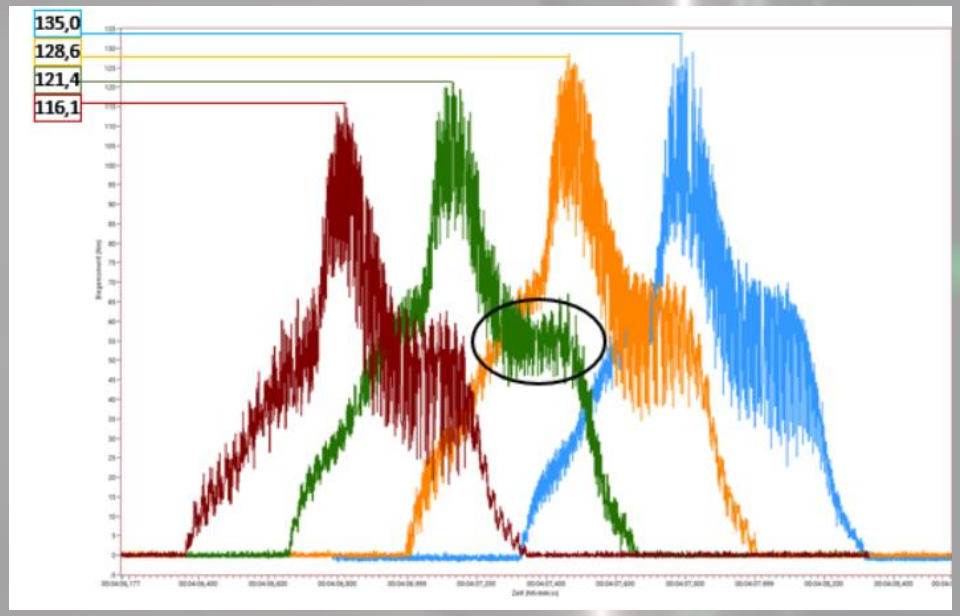
Tool selection for titanium machining

Tool 1

Tool 2

Tool 3

Tool 4



Milling Cutter	Amplitude in the marked area [Nm]	Maximum Bending Moment [Nm]
WZ1	30 Nm	135,0 Nm
WZ2	25 Nm	128,6 Nm
WZ3	10 Nm	121,4 Nm
WZ4	30 Nm	116,1 Nm

→ Selection of **WZ3** due to lowest amplitude and best surface quality

Beschichtungsvergleich – Tool Life Plotting

Coating 1

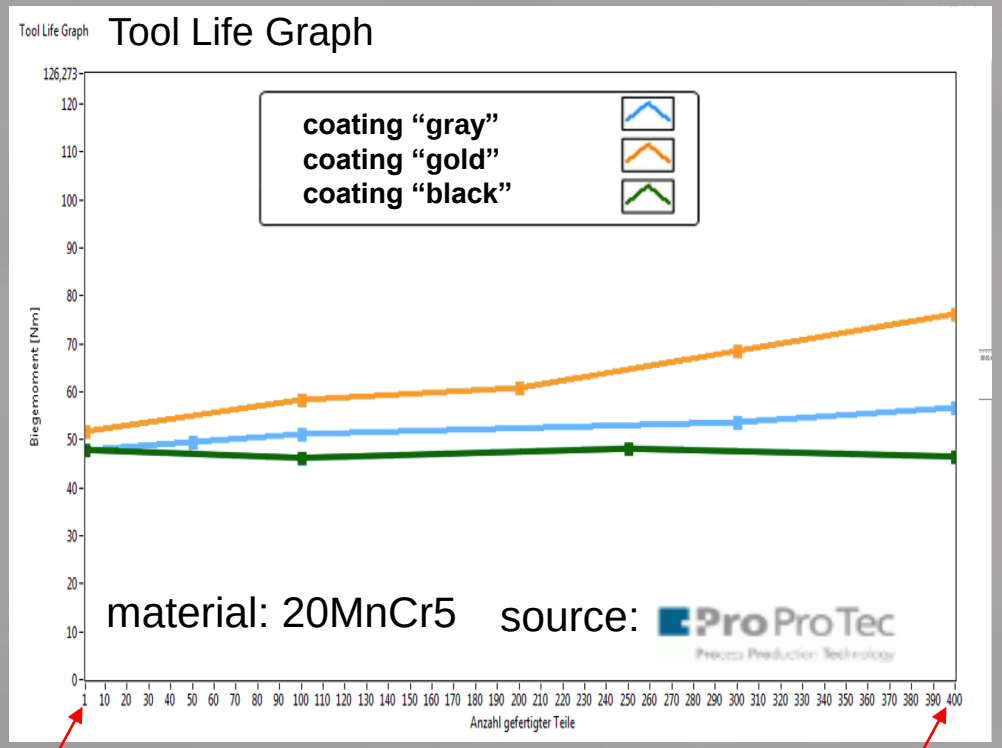
Coating 2

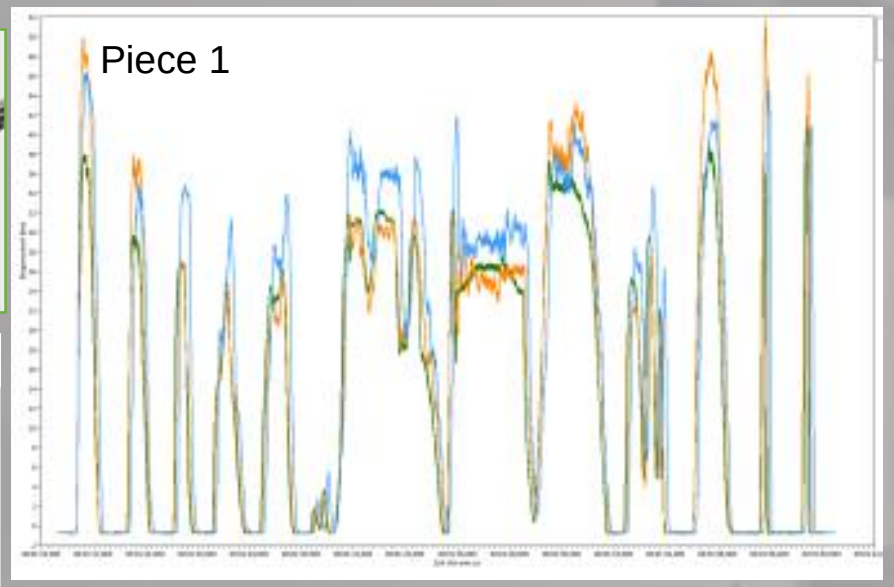
Coating 3

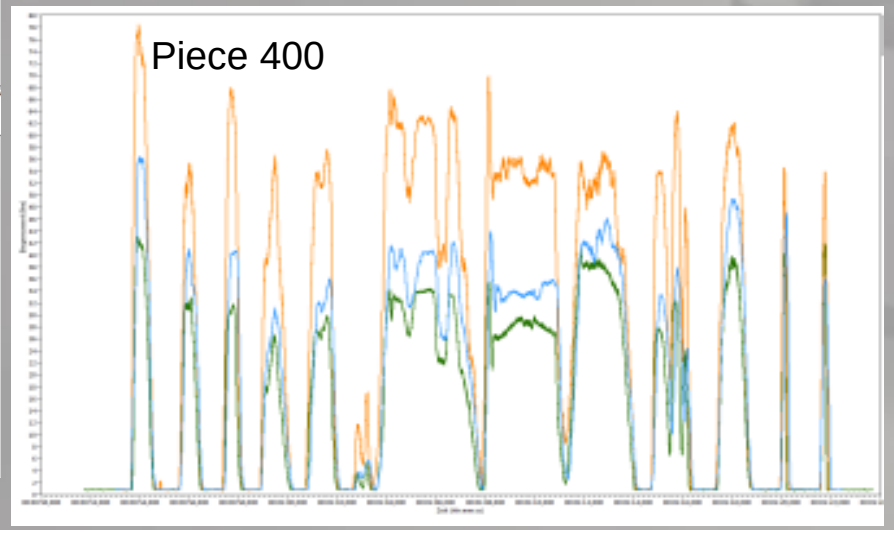
Coating 4

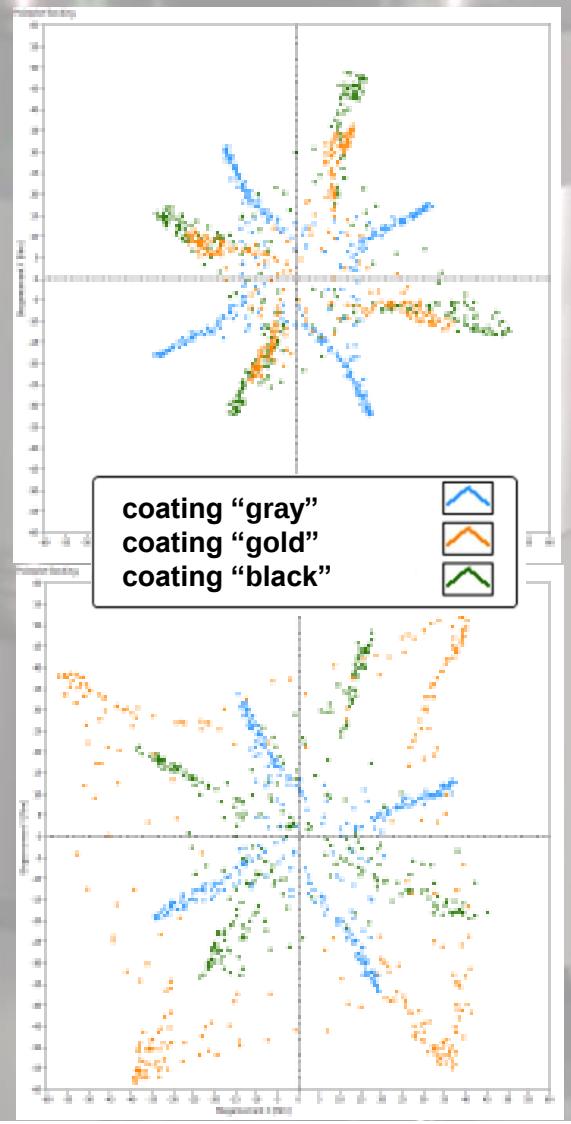
→The **same** tool with **different coatings**

Optimization of coating

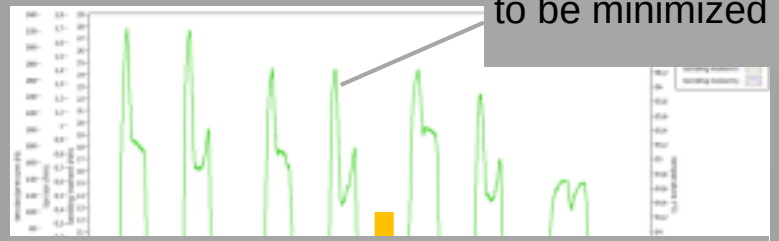








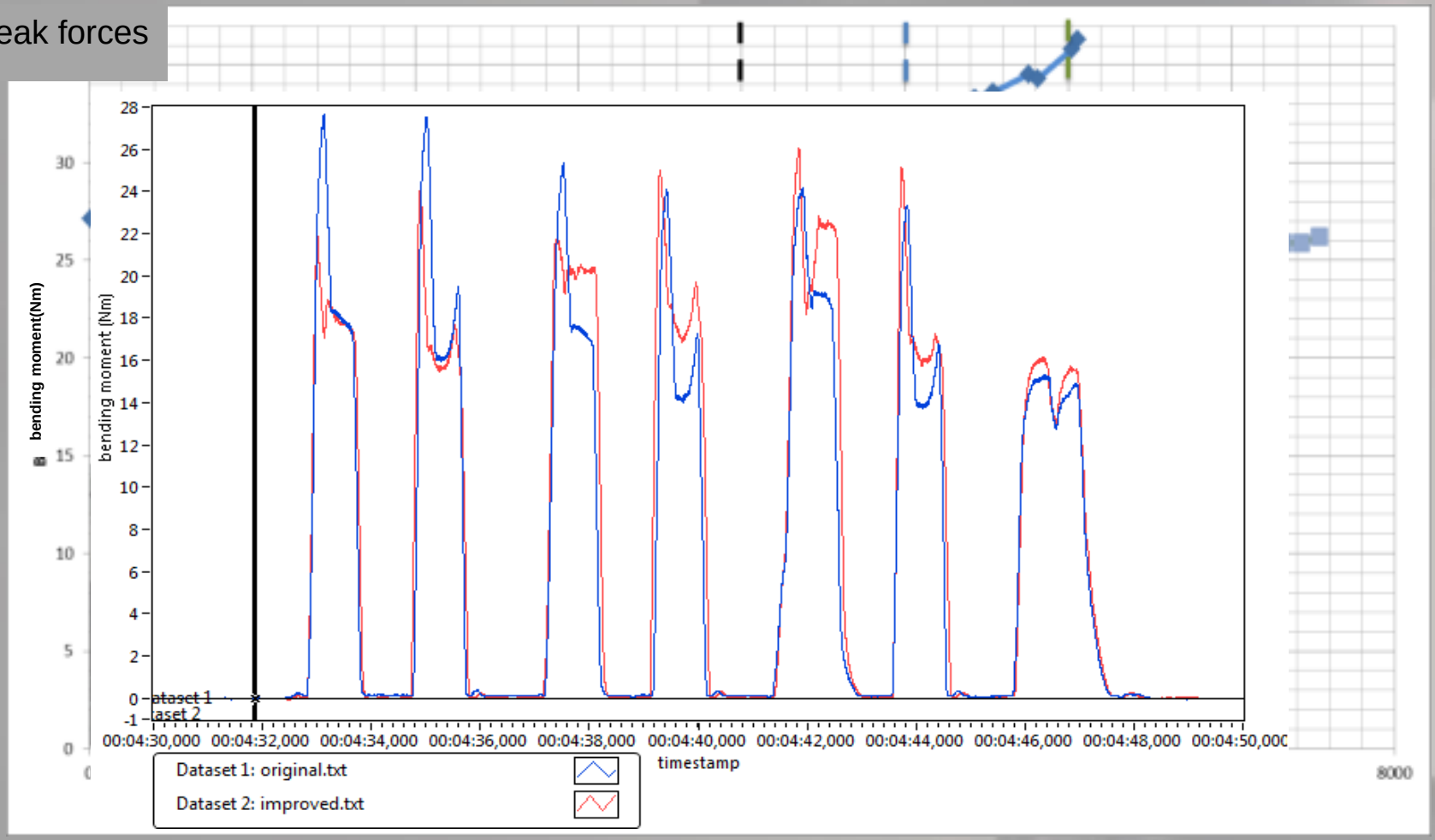
Measurement – Milling notch with 6mm end milling cutter



optimizations:

1. Variation of z-depth:
   from 3 x 3.5 mm
   to 3,0 / 3,8 / 3,7 mm

2. Reduction of feed rate
   at the point of maximum
   tool engagement



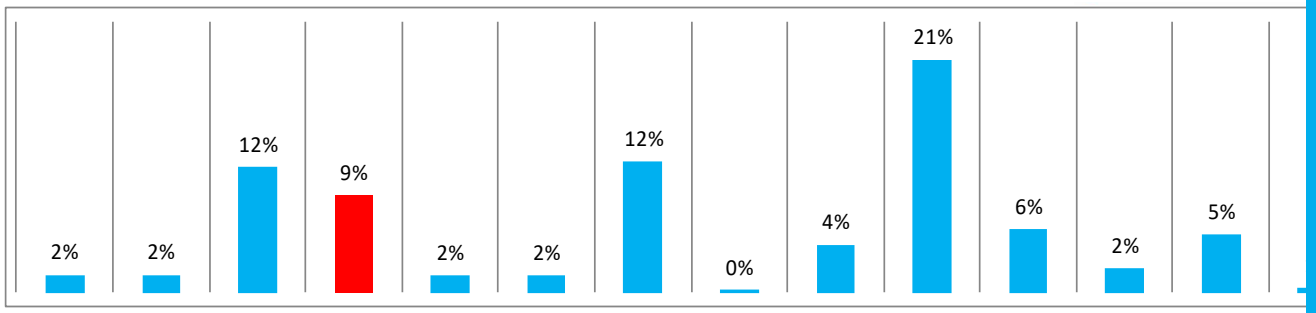
Result: extend of tool lifetime of more than 50% realized

Ex.: Automotive supplier - Milling notch with 6mm end milling cutter

spike system profitability calculation

spike Sensory tool holder

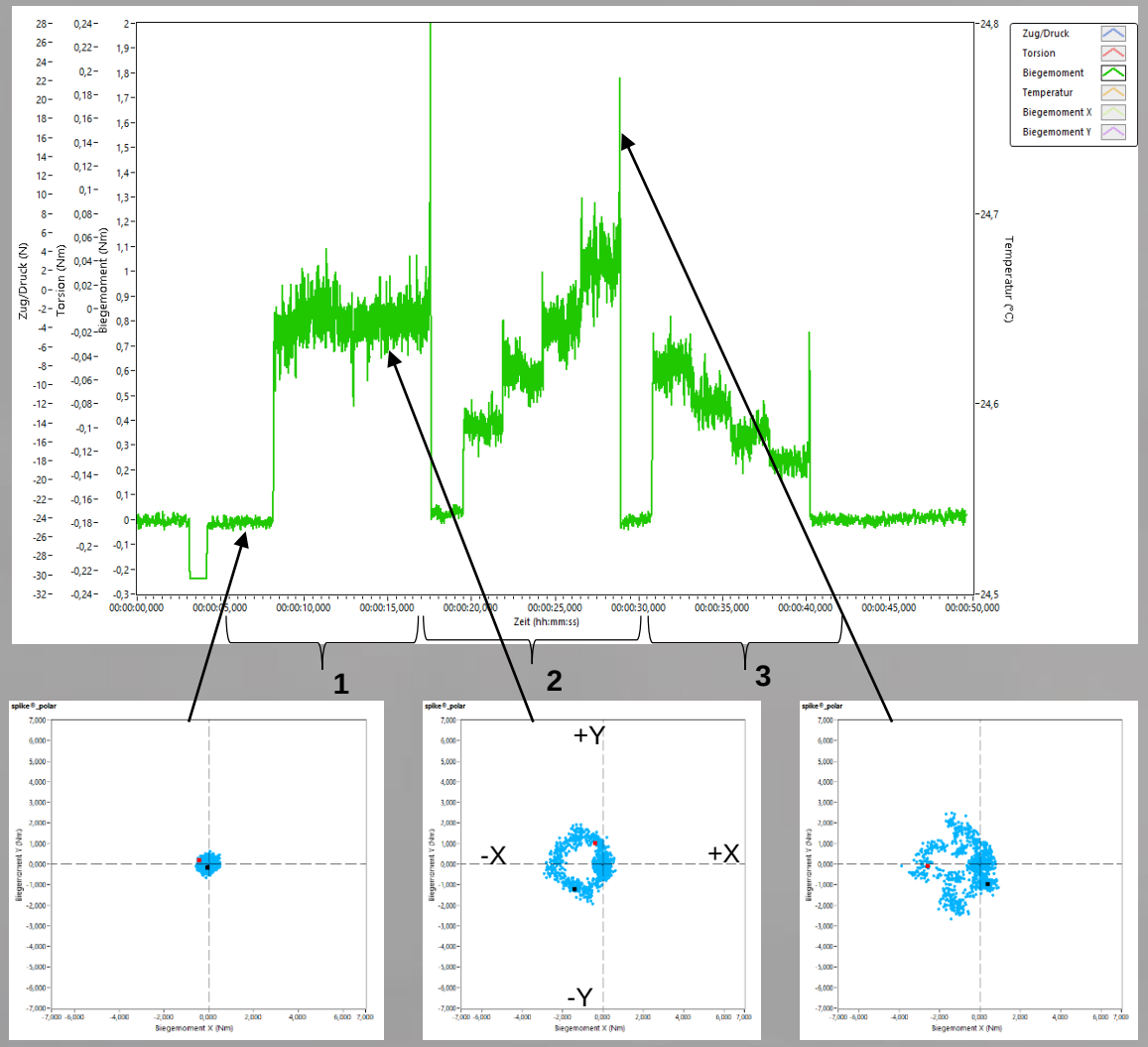
0.07	€	Tool costs in € / piece
180	€	Machine-hour rate
45	min	Tool change time / shift
1,500,000	Stk.	Serial number of pieces / year
4,710	€	Saving tool costs in series per year
3,164	€	Savings tool change costs in series / year
7,874	**€**	**Total savings on tool 3H**



tool number	1H-1	1H-2	2H	3H	5V	7V	8V-1	8V-2	9H	11H	12H	13H	14V-1	14V-2
Service life (number of parts)	6,000	6,000	5,000	4,000	3,000	3,000	1,500	20,000	7,000	4,000	7,000	20,000	7,000	50,000
Share of tool costs in%	2%	2%	12%	9%	2%	2%	12%	0%	4%	21%	6%	2%	5%	1%
Optimization of service life	0%	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tool cost savings in ct / piece	**0.0**	**0.0**	**0.0**	**0.31**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Tool change cost savings in ct / piece	**0.0**	**0.0**	**0.0**	**0.21**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total savings in ct / piece	**0.0**	**0.0**	**0.0**	**0.52**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Result: 7800€ per year by only one tool

Detection of the concentricity error



Deep Delivery	Process Section a_p [mm]	Page Delivery a_e [mm]
1	10	0,02
2	6	0,01 – 0,02 – 0,03 – 0,04
3	4	0,04 – 0,03 – 0,02 – 0,01

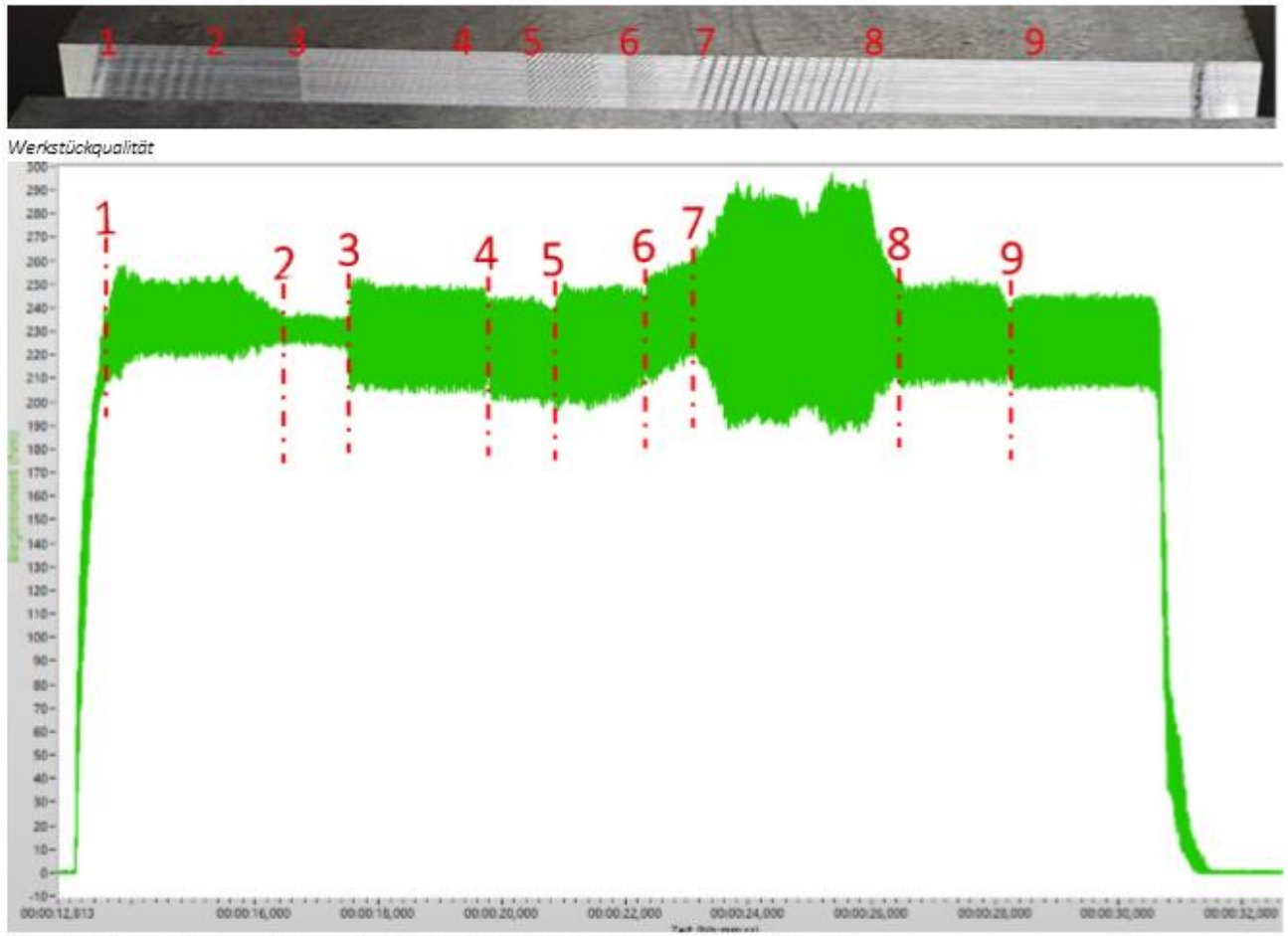
Shift of the center point in -X direction in spike_polar

→ Asymmetrical division of cutting forces

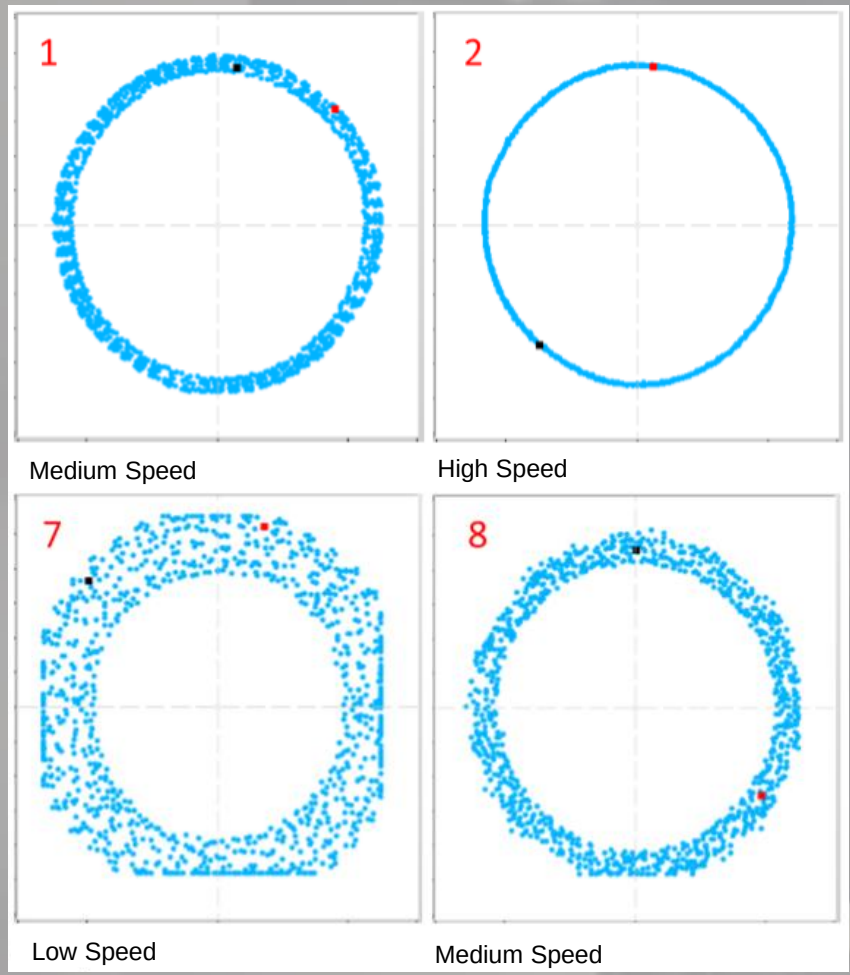
→ Concentricity error of 6µm could be measured

Milling – Speed Variation (+/- 15%)

9. Correlation of surface quality to bending moment



Bending moment (without filter) of the 3rd track of the roughing cutter: vc=110, n=2100, d=16, ap=16, ae=16, z=4



Medium Speed

High Speed

Low Speed

Medium Speed

spike® Wear analysis and tool life time

promicron wireless solutions

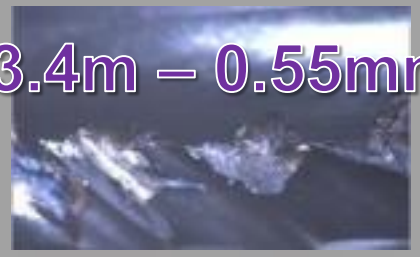
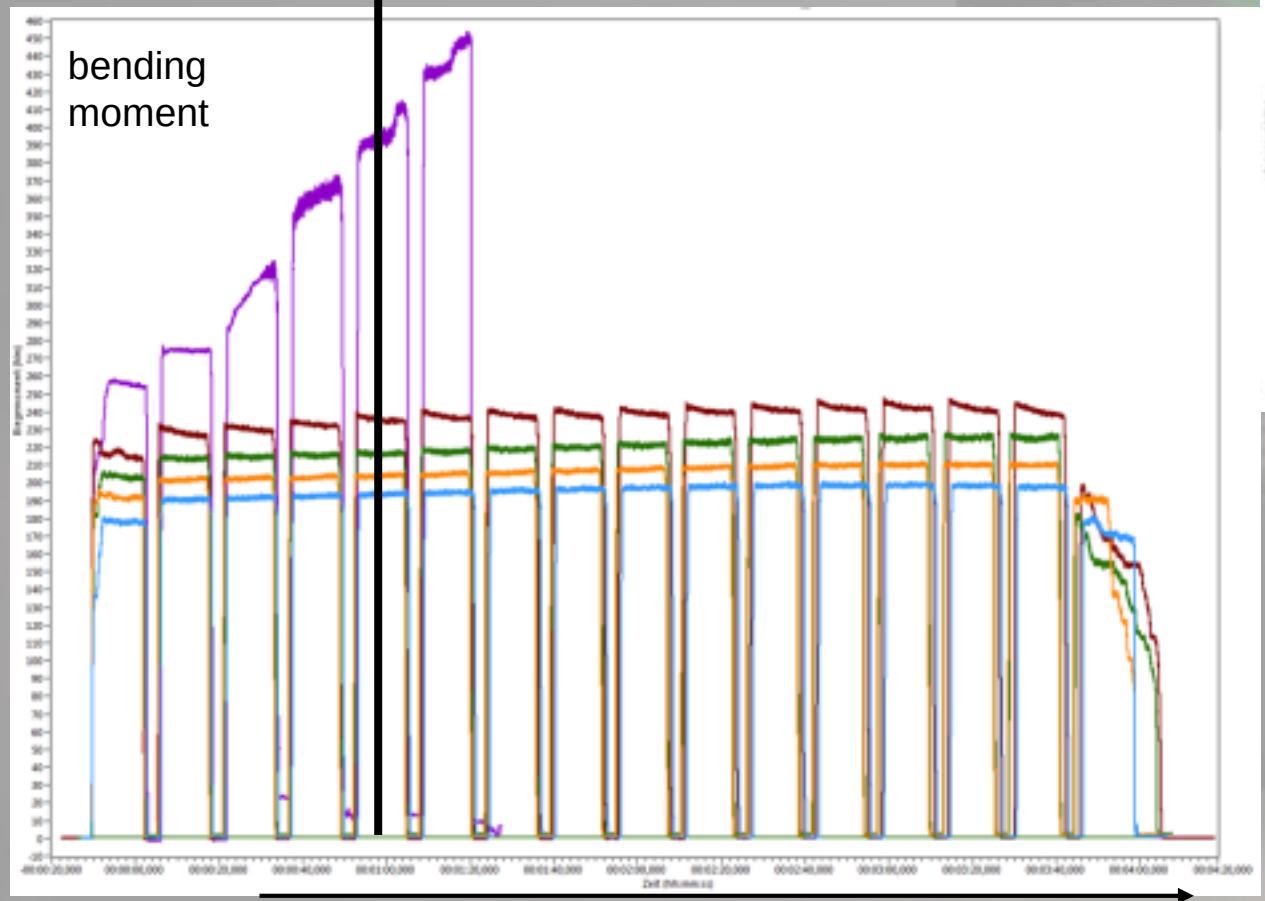
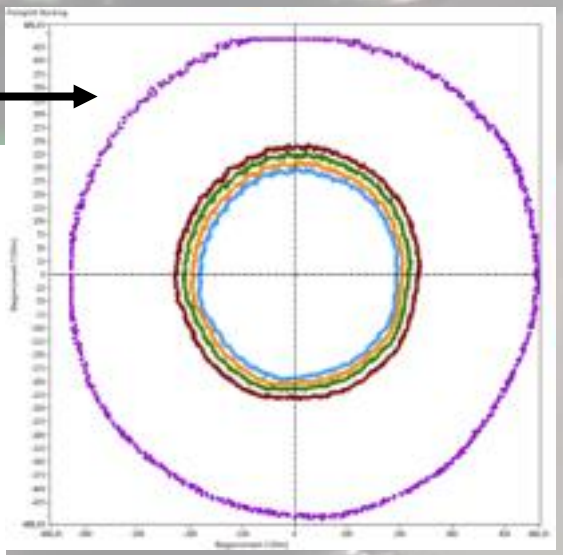


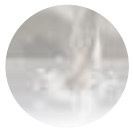
fig.1 toolpath





spike_polar





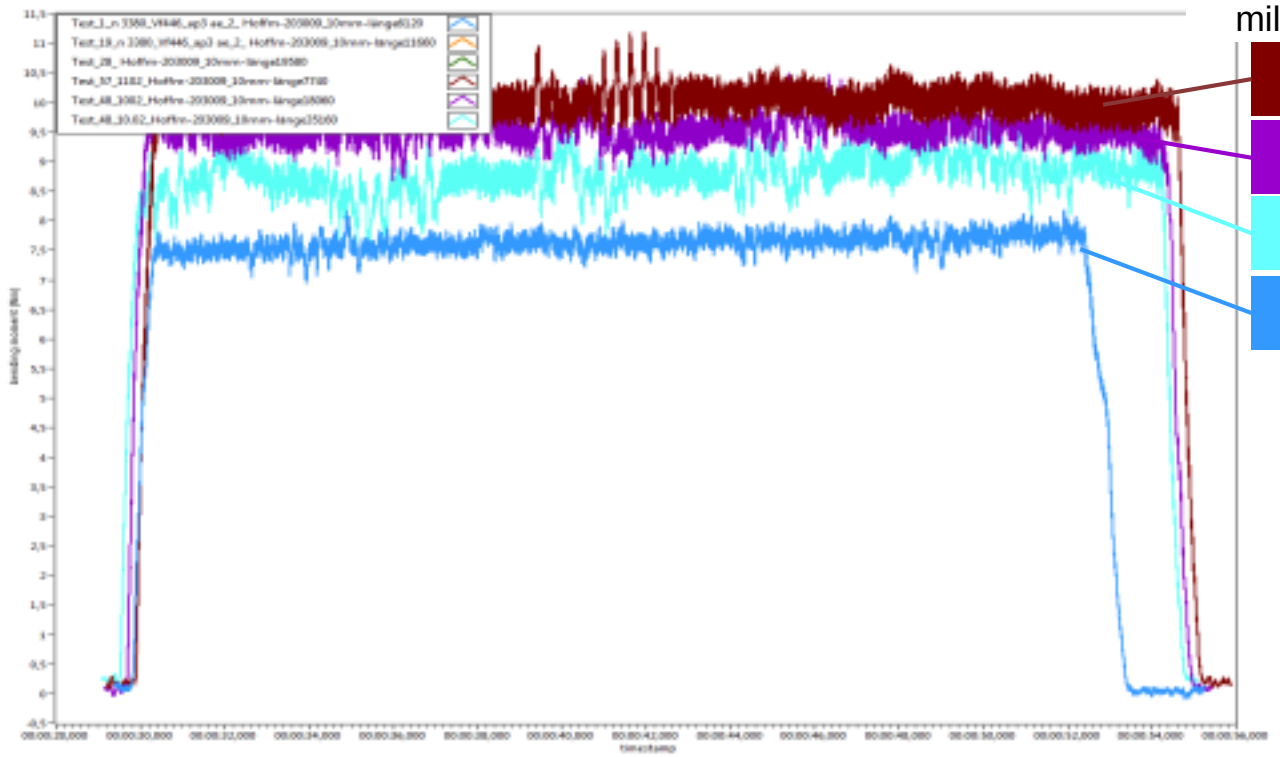




Wear evaluation by bending moment

process: carbide milling cutter (Ø 10mm), material 42CrMo4
vf = 446 ae = 2
n = 3380 ap = 3

bending moment



milling travel

74 m

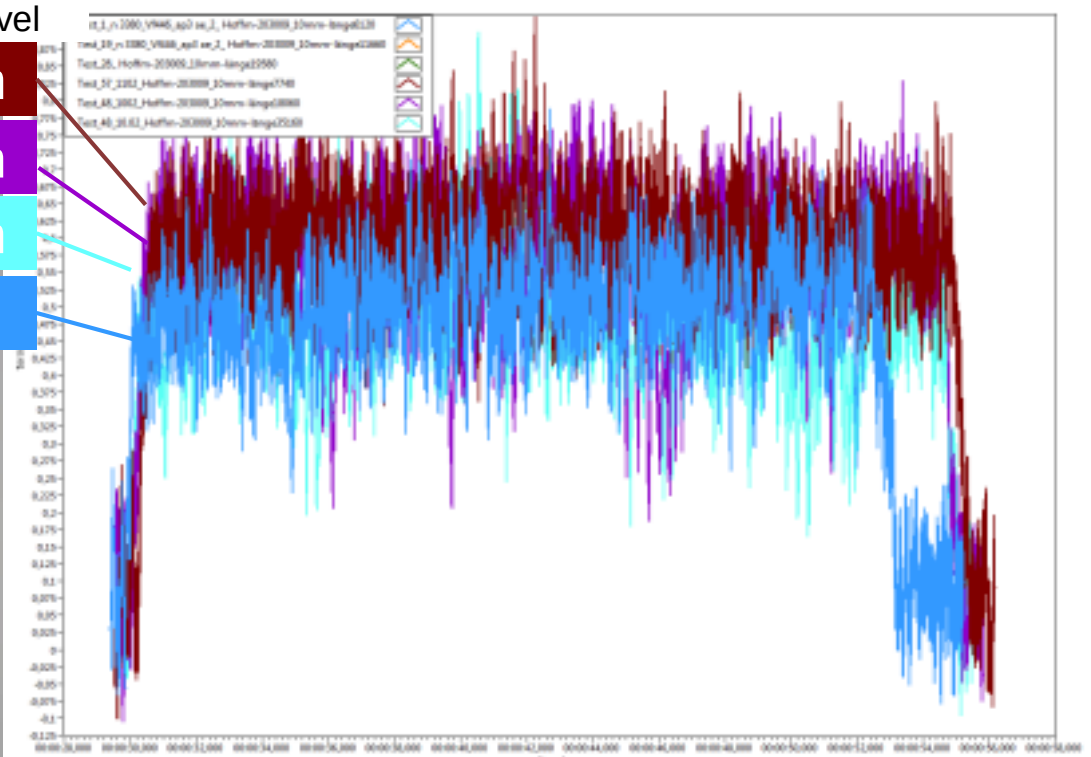
47 m

35 m

0.8 m

Increase of bending moment of 30% at a measured wear of 0.13 mm.

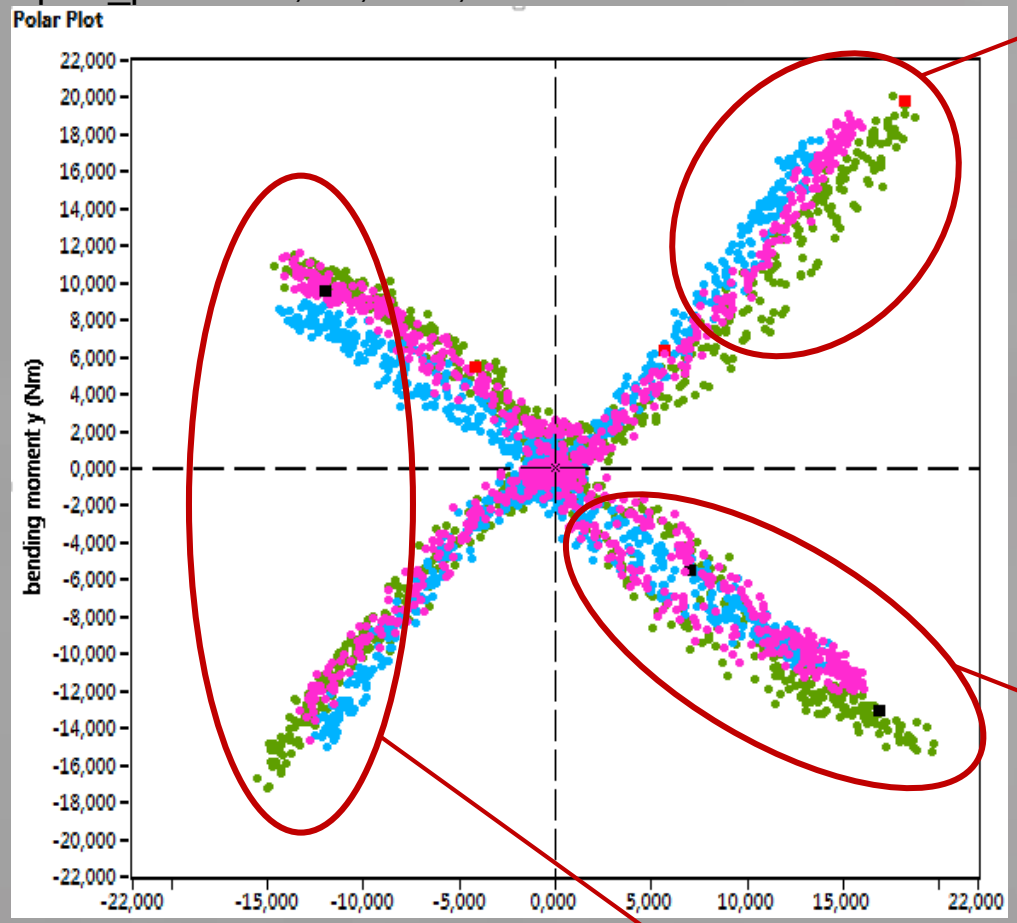
Torsionsmoment



force-noise-ratio of torque is significantly less.

Wear evaluation by bending moment

spike_polar at 0,8m, 35m, 74m

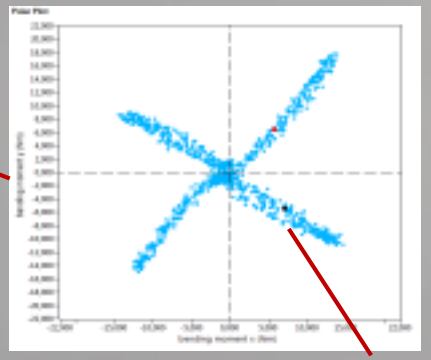


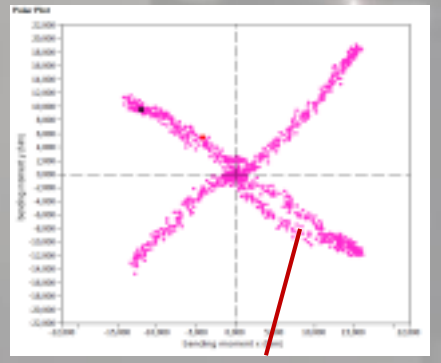
change the resultant force vector by specific wear

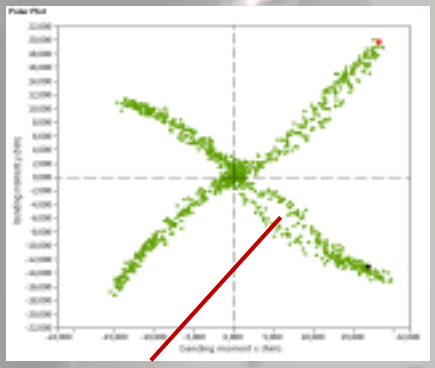
wear: 0,8m

35m

74m







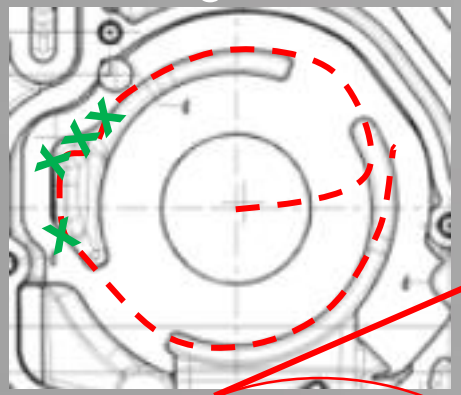
force distribution at flute changes by material welding.

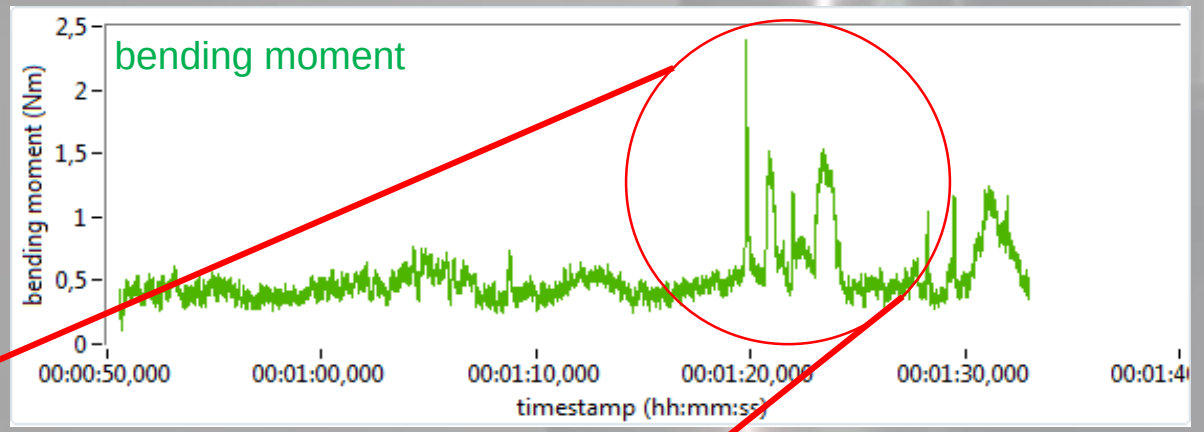
different wear each cutting recognizable

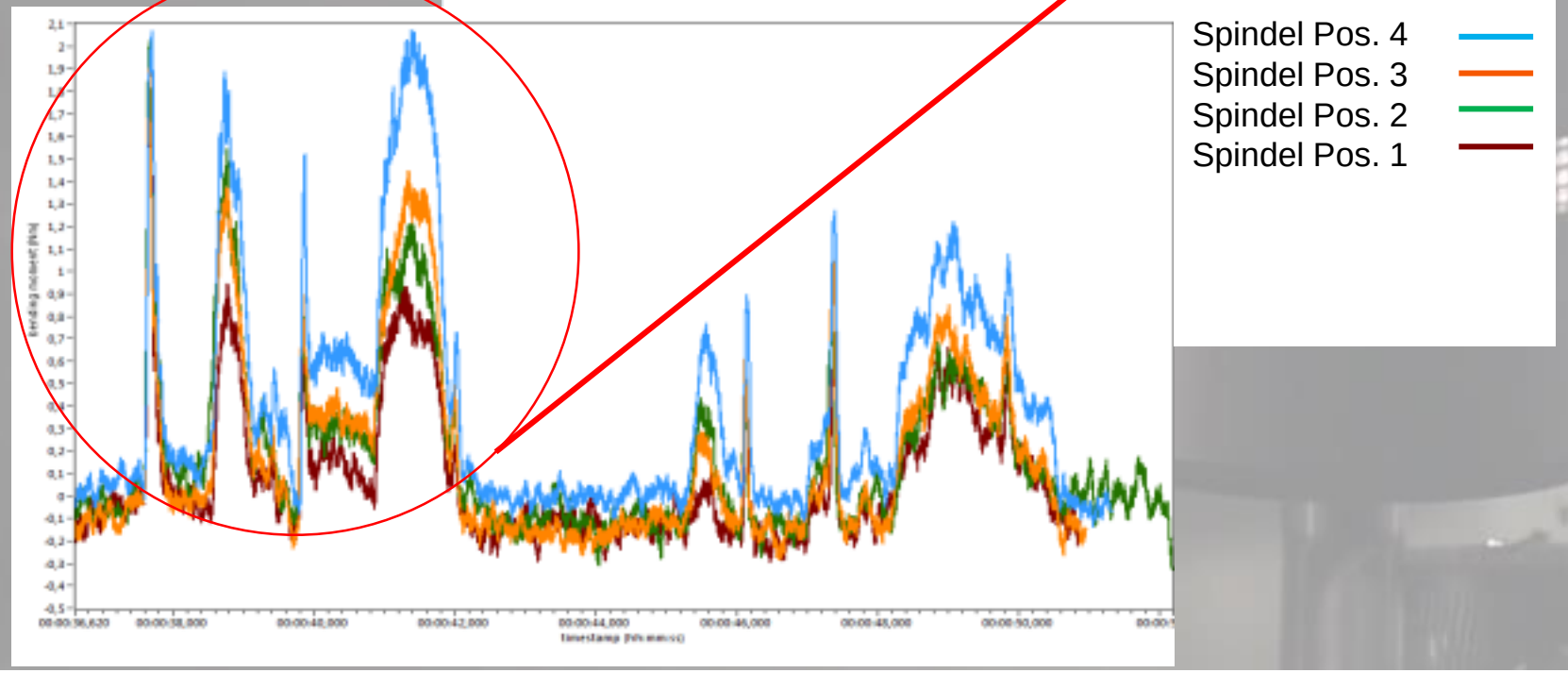
Workpiece positioning

Pos. 1
Pos. 3

Pos. 2
Pos. 4



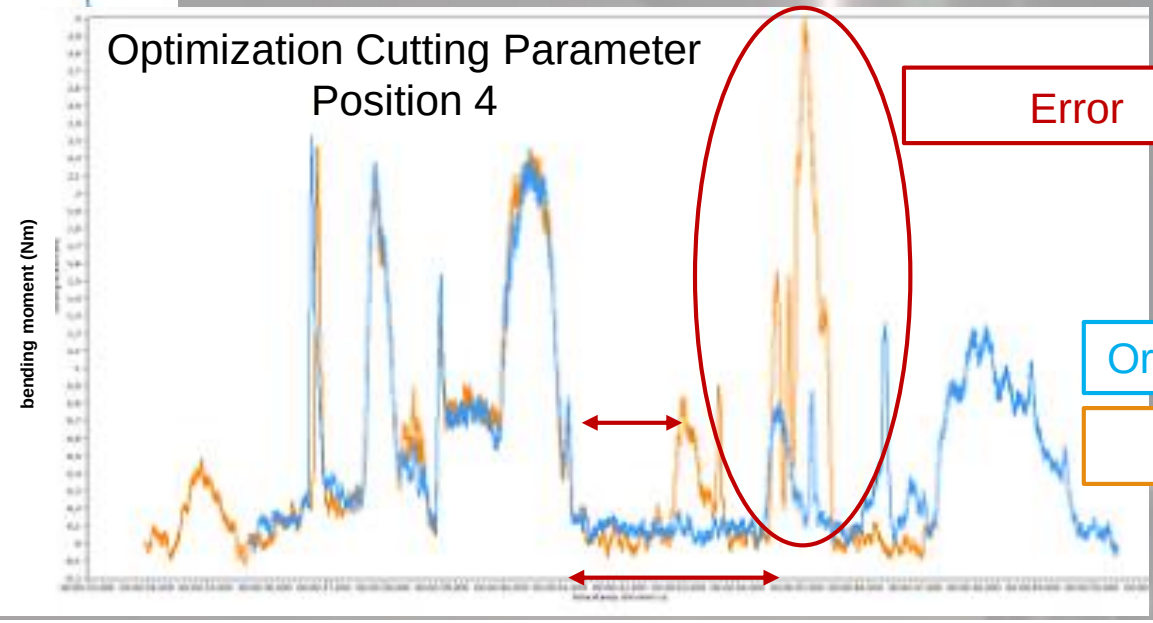




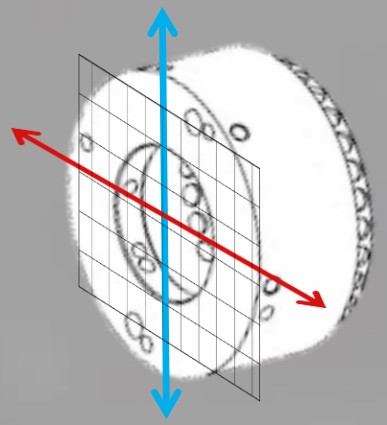
Spindel L

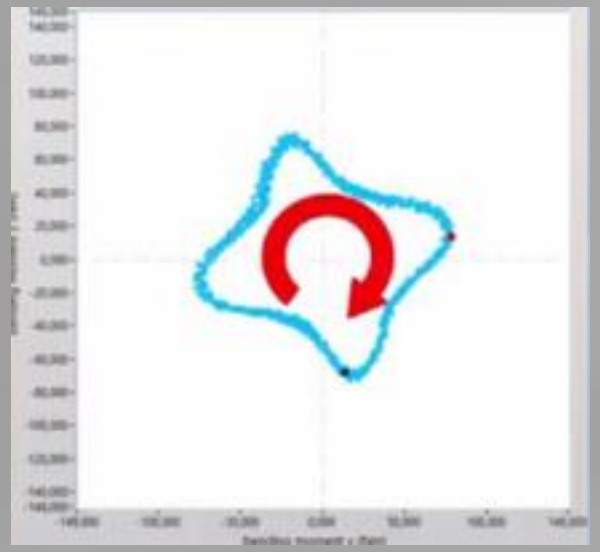
Spindel R

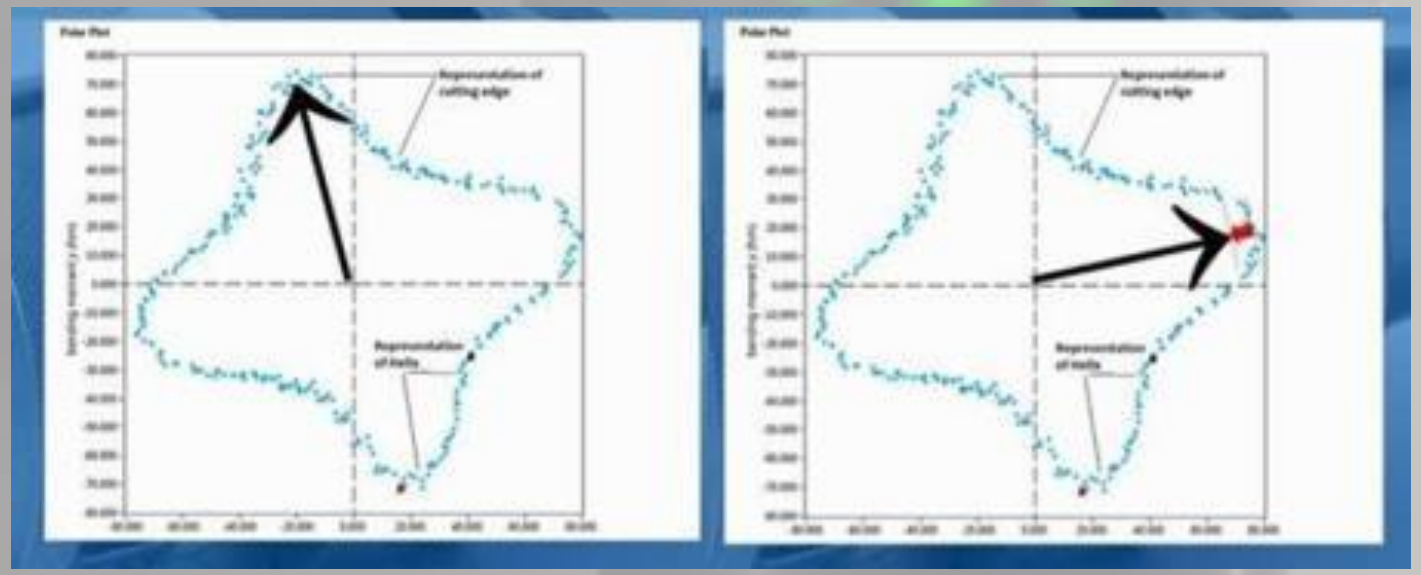
spike® Cutting parameters optimization



spike_polar helps to develop tools



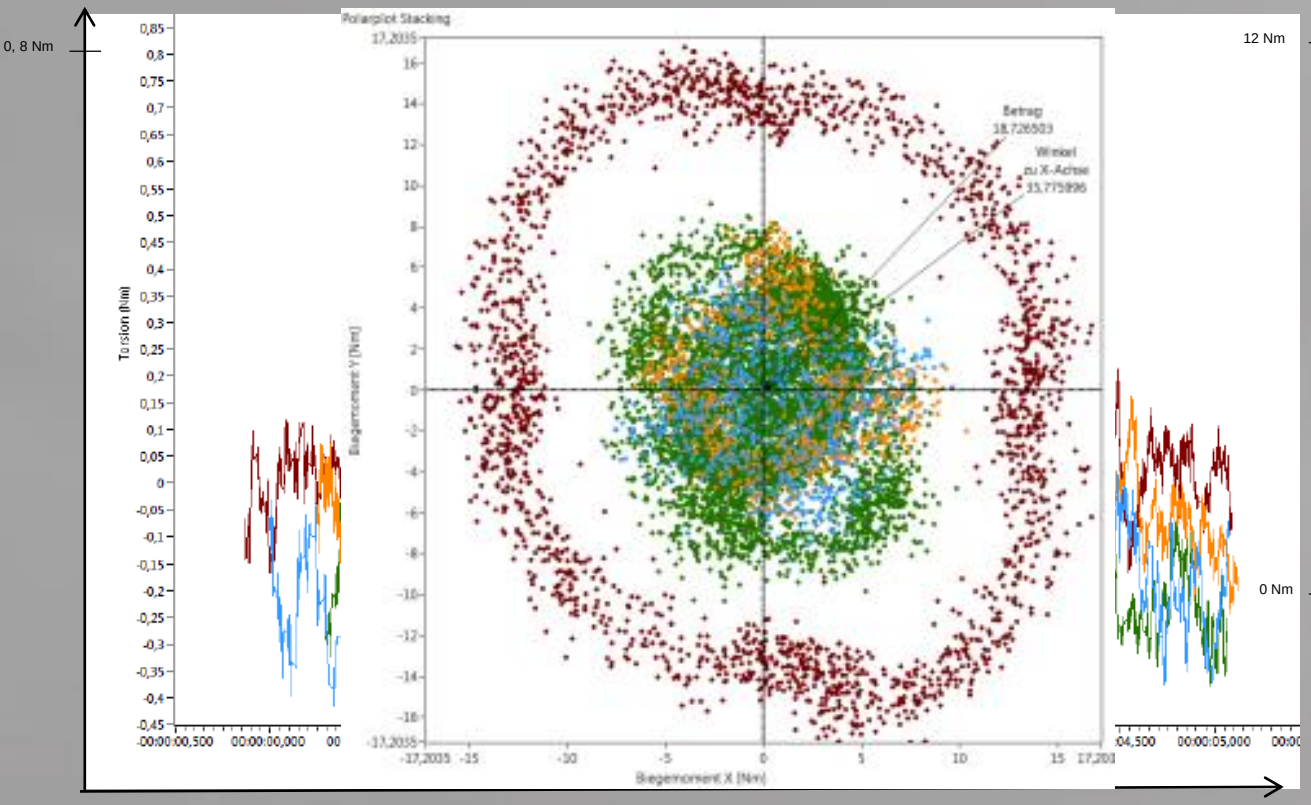


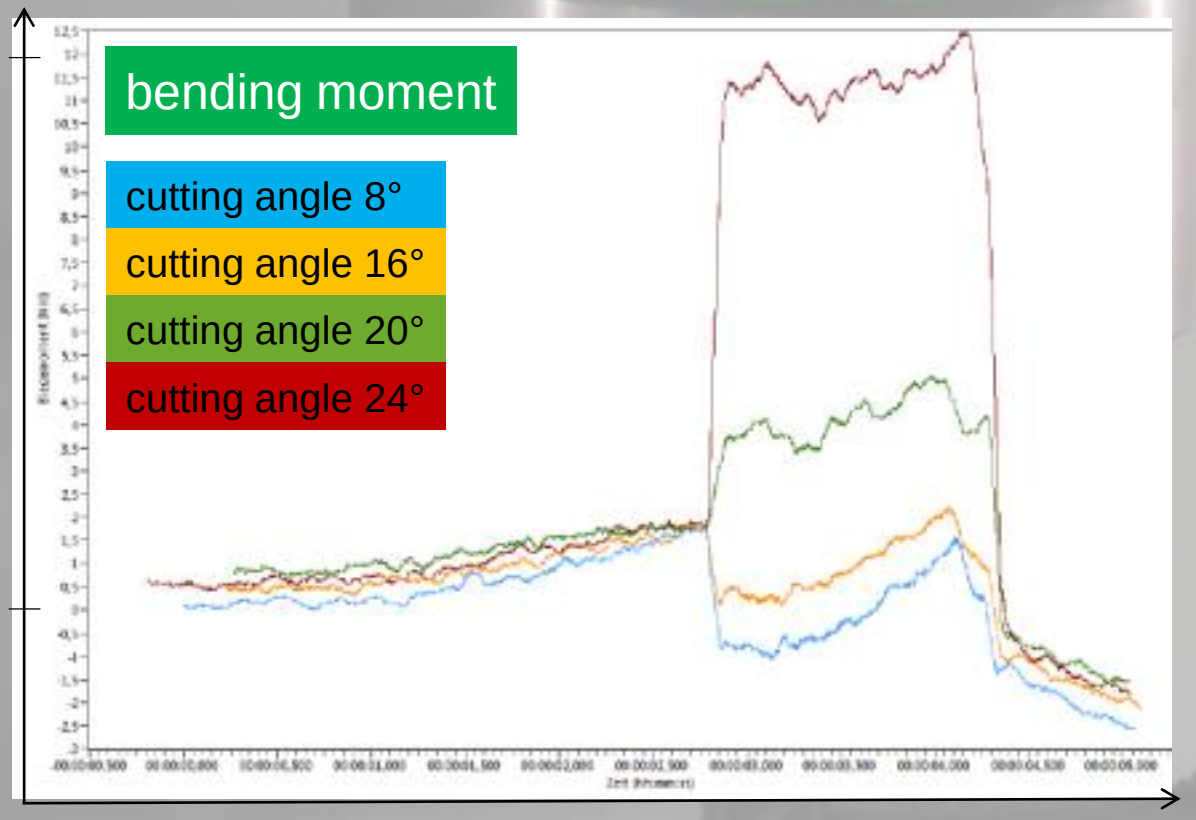


Profile of the tool
with ae = 2 mm, ap = 6 mm

→ Visualization of cutting edges and helix
→ 2 ° different angle of helix rise leads to differences in force values

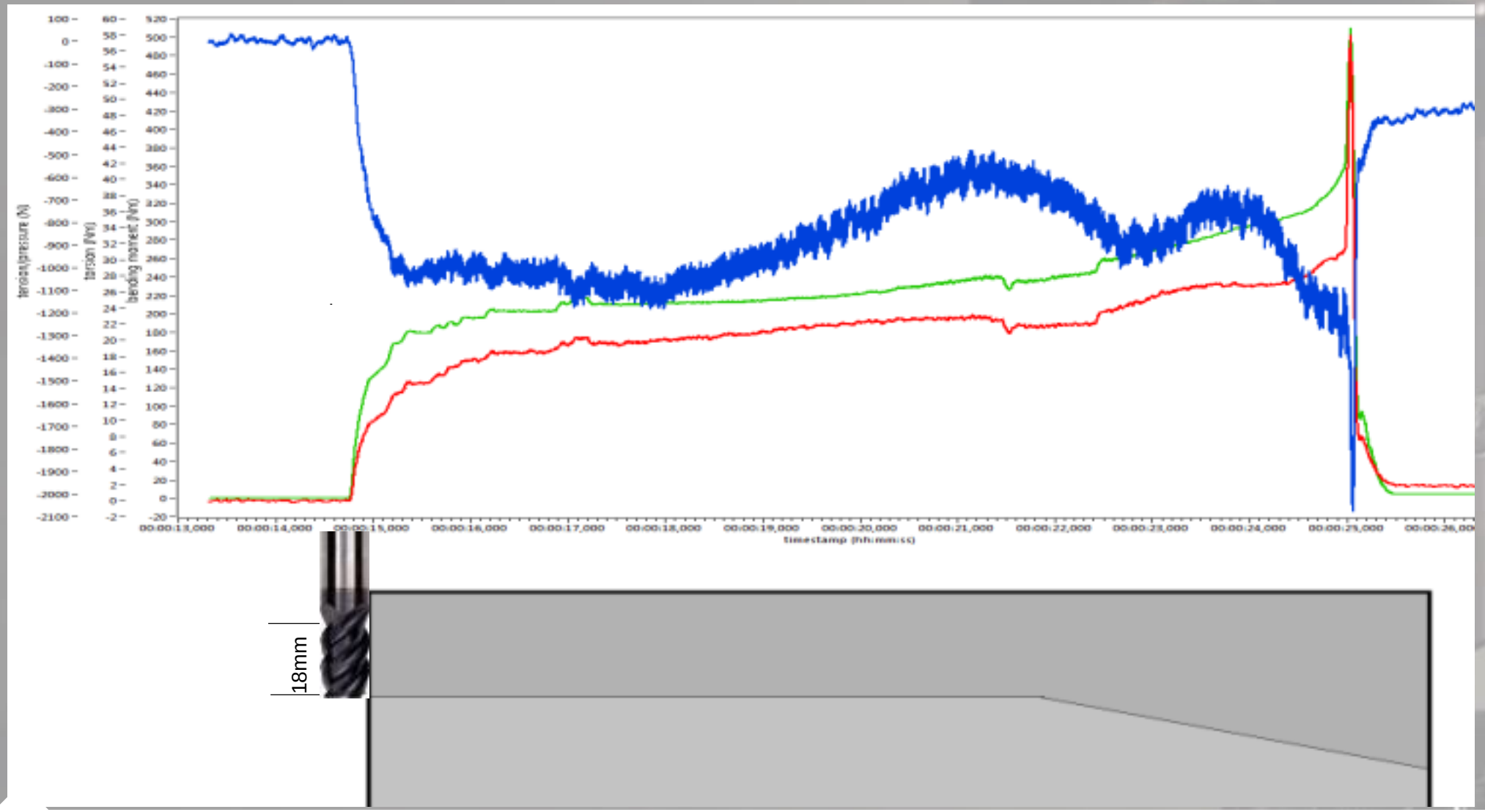
torsion & bending moment when changing the cutting angle





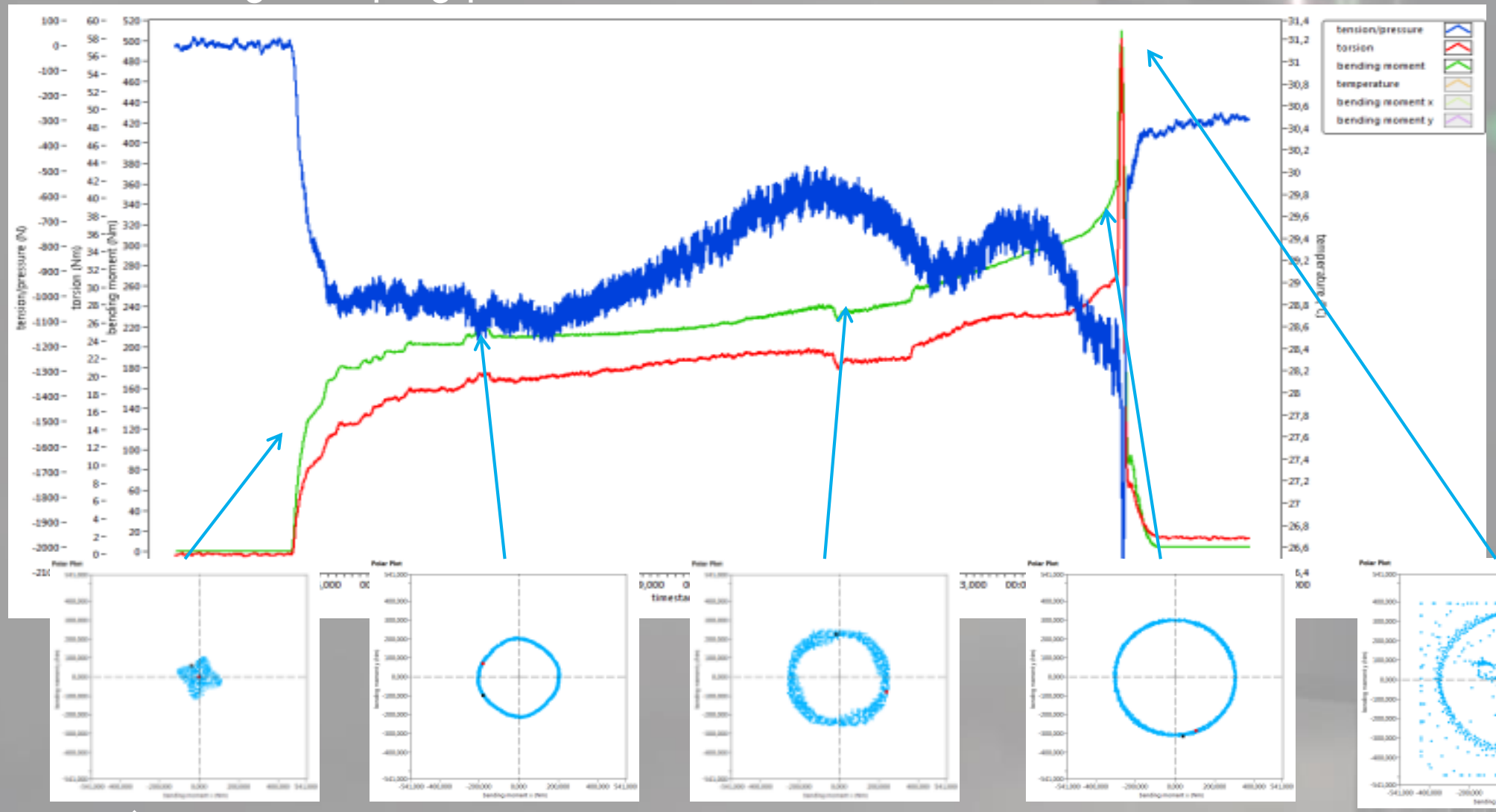
Detecting clamping performance

Techn. Data:
Ø= 12
z=4
ap=18mm
ae=6,9mm
vc=140 m/min
n=3713
f=0,06
vf=222,78

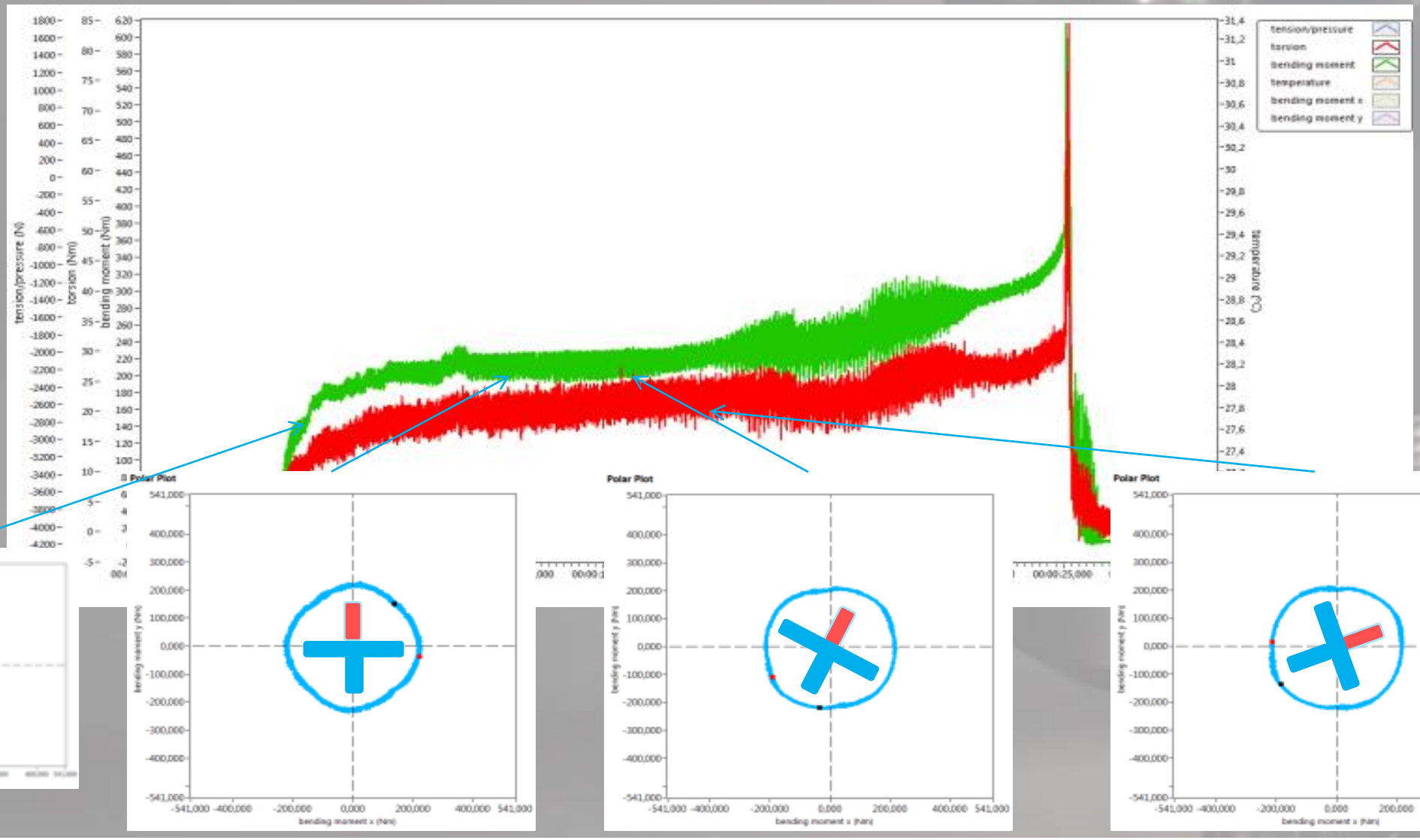


spike® Detecting clamping performance

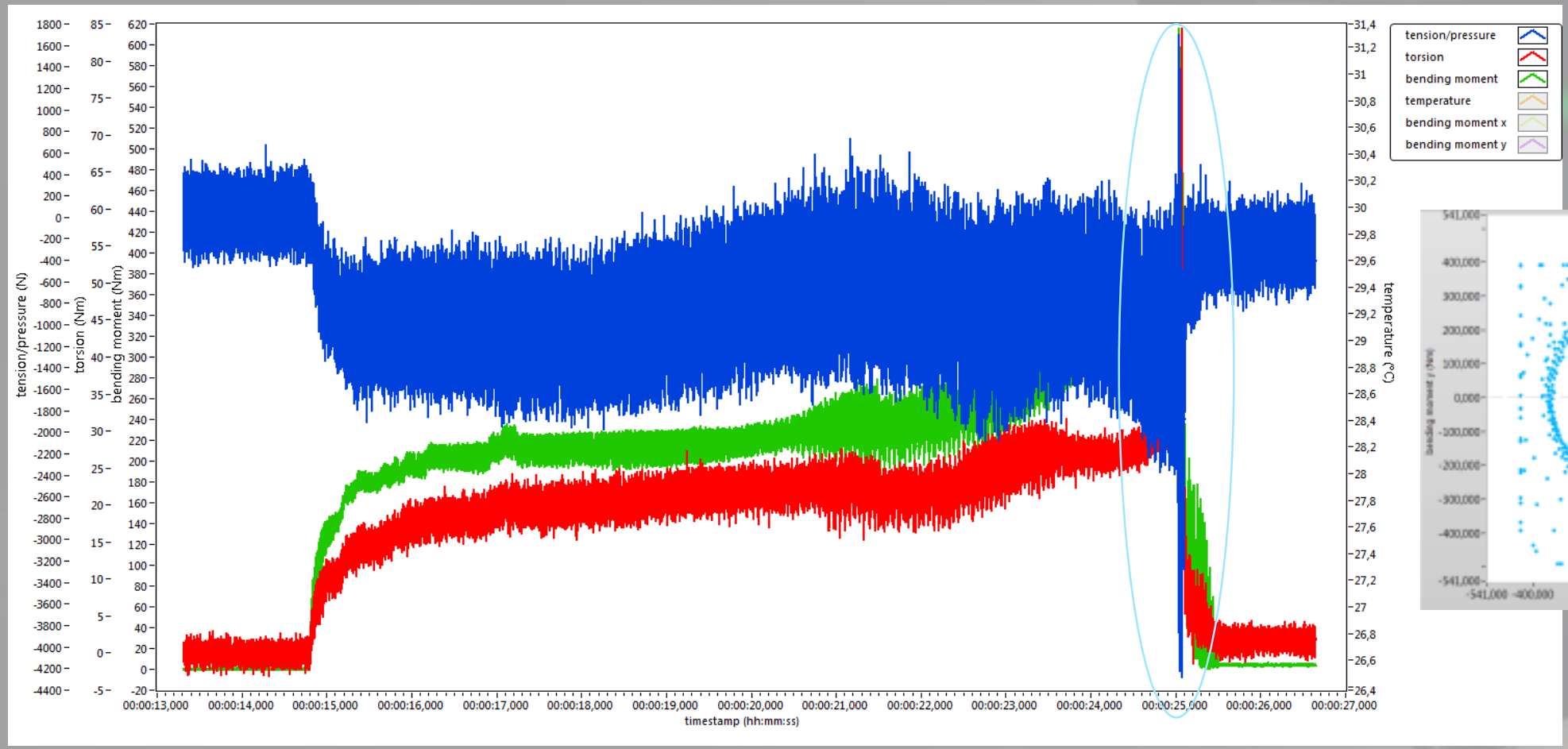
promicron wireless solutions

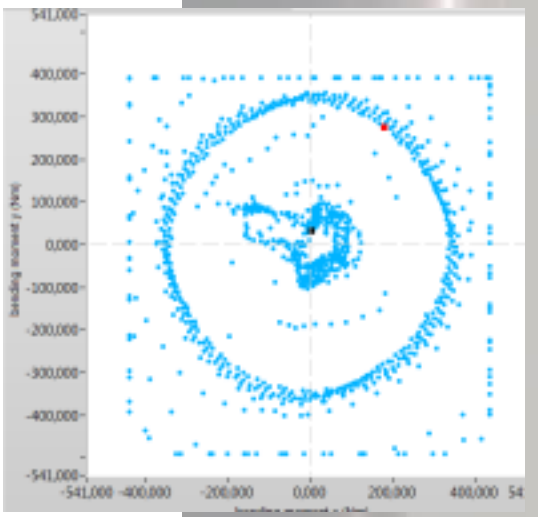


Detecting clamping performance – Moving tool



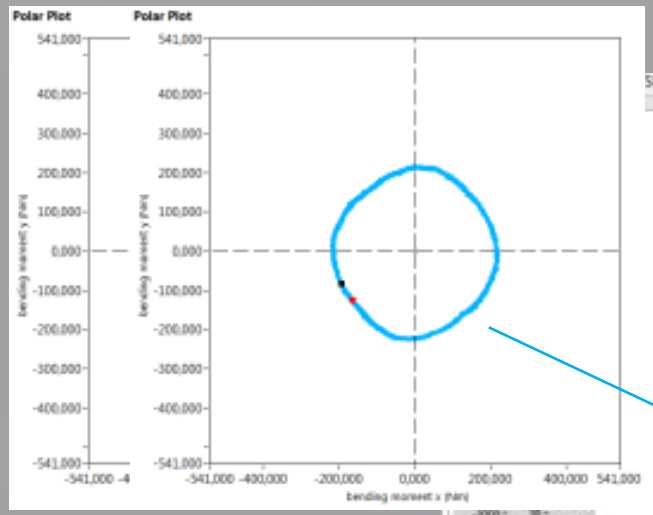
Detecting clamping performance – Moving tool

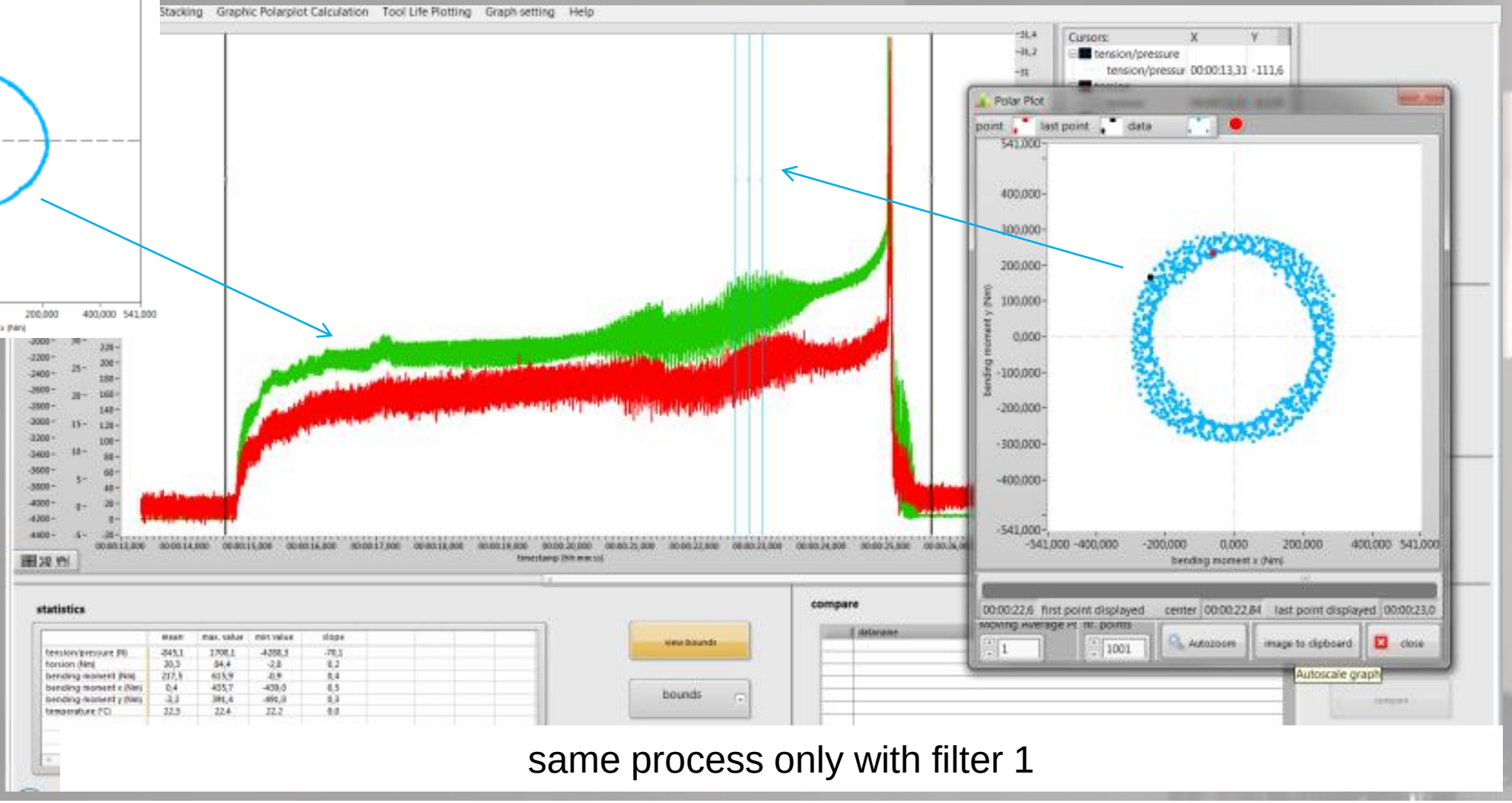




same process only with filter 1

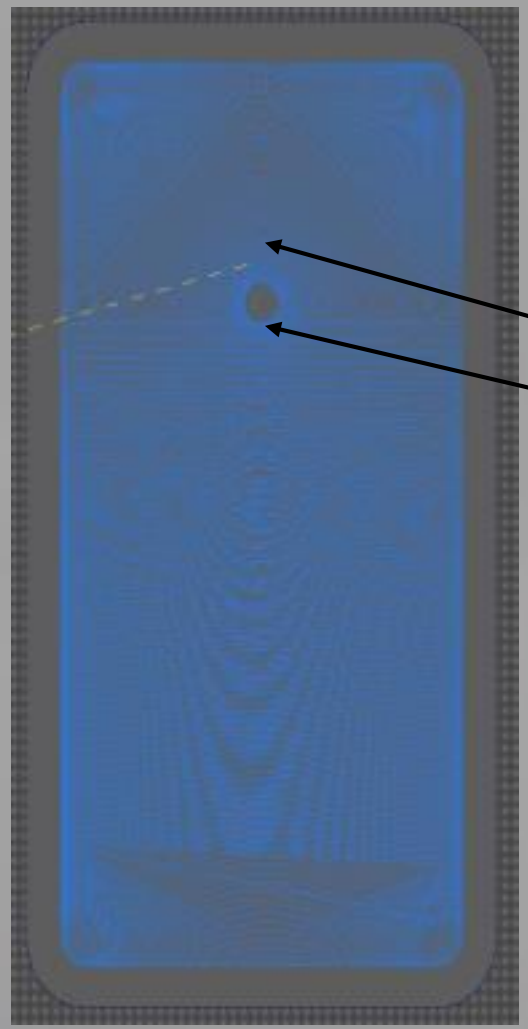
Detection clamping performance – Vibrations



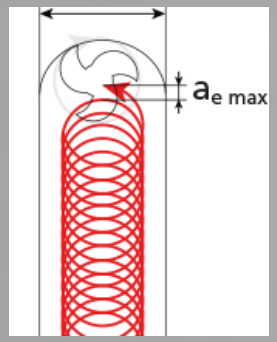


same process only with filter 1

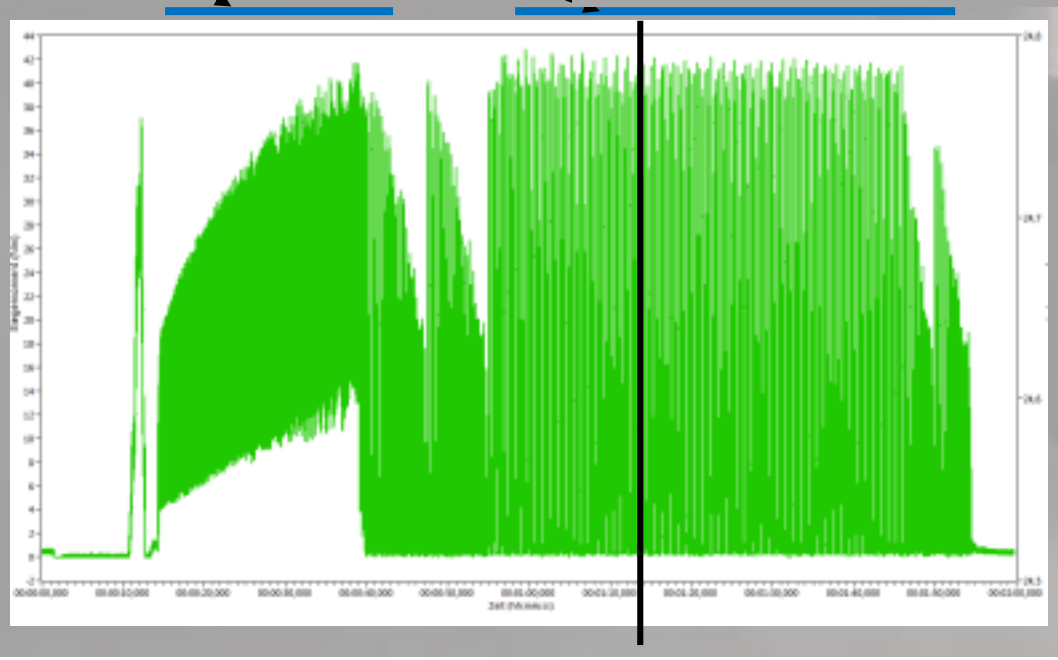
Trochoidal Milling

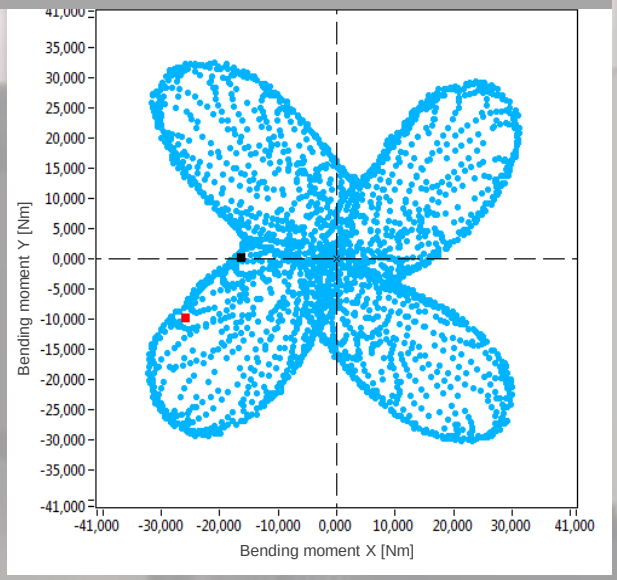


muzzle in trochoidal milling



The trochoidal milling ensures a uniform load of the tool.
The milling cutter processes the workpiece over the entire depth with the entire cutting length.
This is recognizable by the strong contours of the spike_polar.
This leads to lower cutting forces with the same distribution.
As a result, higher processing speeds and longer service life are possible.



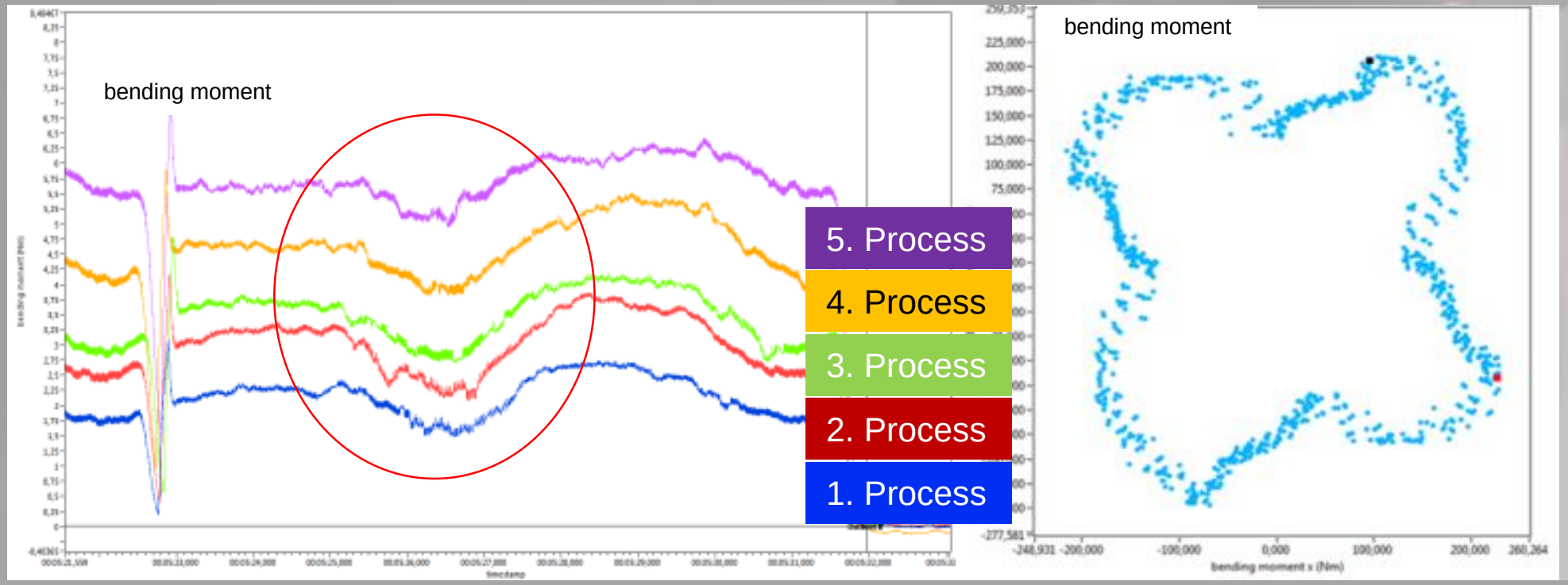


Spike_polar with 5000 points = 2 sec.
Zeit: 1:12 – 1:14

spike® Material test / Machine diagnosis

promicron wireless solutions

radial milling



Result:

- Support of calculation of tool life time of unknown materials with direct wear measurement
- „dent“ in force deflection is an indicator for loose steering mechanism
  <u>information afterwards</u>: spindle bearing defective! – has been replaced

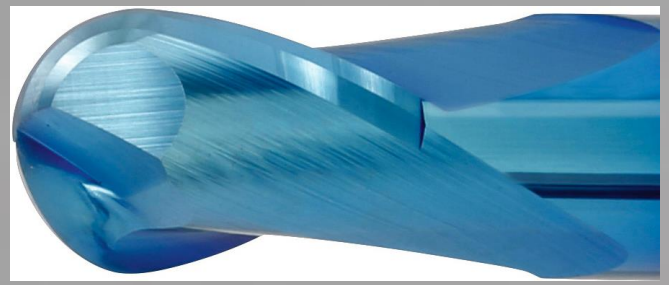
Application in Tool and Mould Construction spike®_kpi

Workpiece:

Material:
1.7227 (42CrMo4 quenched and tempered)
(heat-treated Steel R_m≈1000MPa)

Process Parameters :

v_c:	220 m/min
$a_{e,p}$ = 0,6 mm	
f_z:	0,095 mm/Z

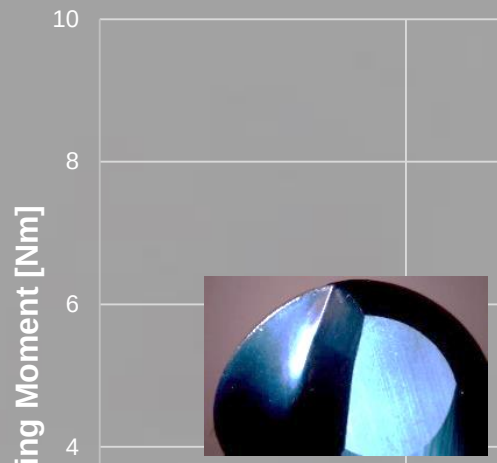


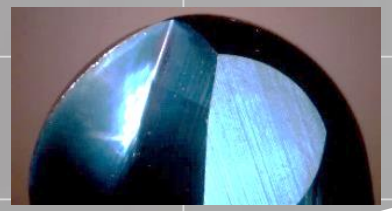
Tool:

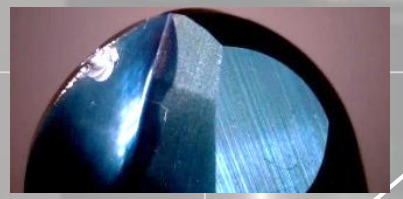
207362 12
GARANT Diabolo VHM-Vollradiusfräser HPC

Example for Mould Construction

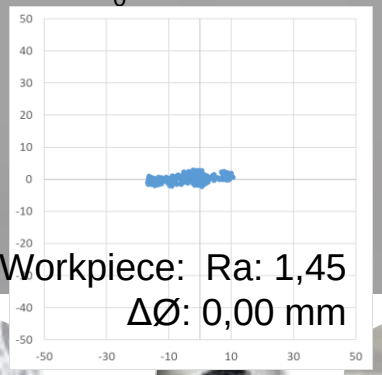
Tool Life Analysis Bending Moment



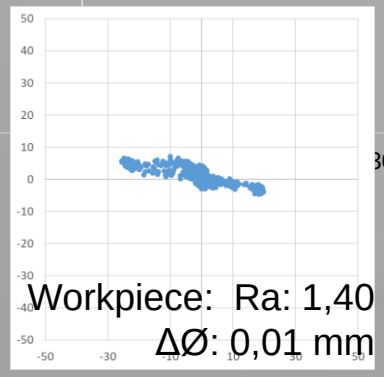




Cutting Break



Workpiece: Ra: 1,45
ΔØ: 0,00 mm



Workpiece: Ra: 1,40
ΔØ: 0,01 mm

Workpiece: Ra : 1,30
ΔØ: 0,02 mm

Workpiece: Ra: 1,20
ΔØ: 0,06 mm

Insights:
1. Better surface quality at
2. Bad component dimensions

spike® spike®_KPI calculation

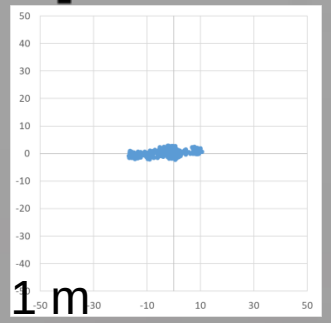
promicron wireless solutions

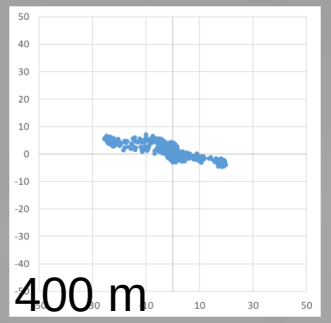
spike®_polar

spike®_kpi relative bending moment increase

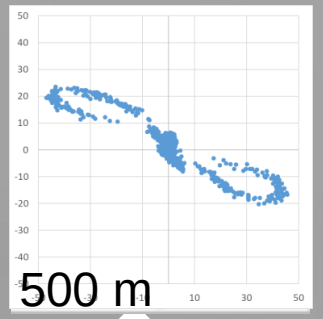
spike®_kpi

Tool path: 1 m





400 m



500 m

Δ 90 %

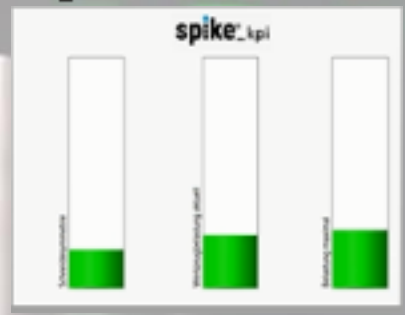
100 m

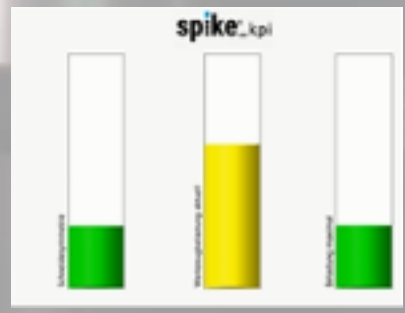
Δ 58 %

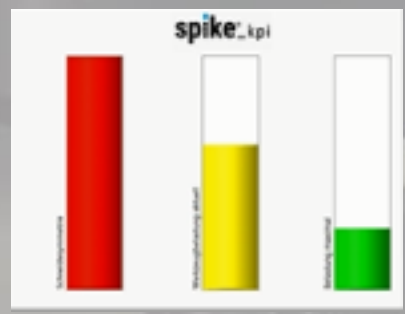
100 m

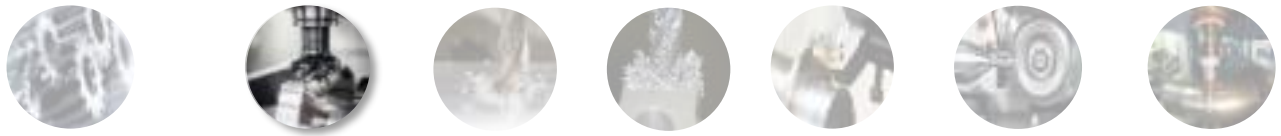
Δ -14 %

100 m









Where do you get these values?

- spike®kpi Max. bending moment und spike®kpi symmetry will be shown soon in the Toolscout software as reference :

Merkmale	Schnittdatenanzeige
Nasswert	
Werkstoff /Werkstoffgruppe	1.2379
Eingriffsbreite ae [mm]	6
Schnitttiefe ap (bezogen auf einen Schnitt)[mm]	6
Schnittgeschwindigkeit Vc [m/min]	110
Drehzahl n [1/min]	2920
Vorschub f [mm/U]	0,4
Vorschub je Zahn fz [mm]	0,08
Vorschubgeschwindigkeit vf [mm/min]	1170
Schnittleistung Pc [kW]	2,764
Drehmoment Md [Nm]	9,046
Hauptzeit th [min]	–
spike®kpi Rel. bending moment [%]:	67,00

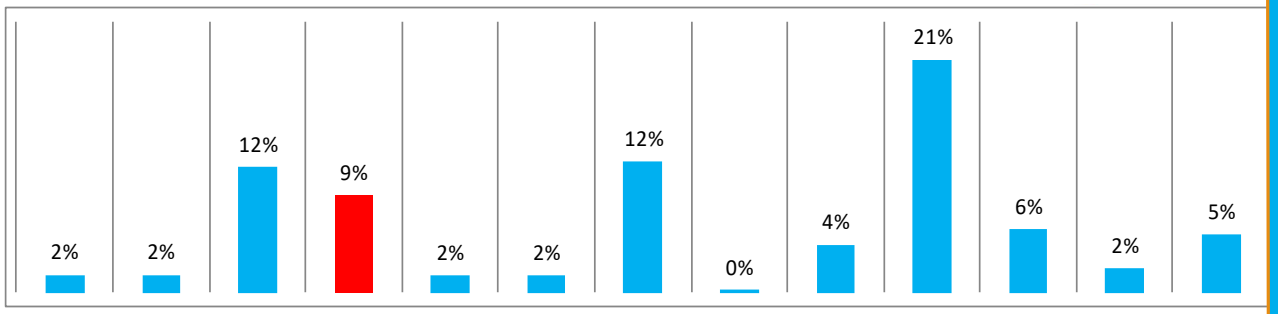
spike Amortization

promicron wireless solutions

spike system profitability calculation

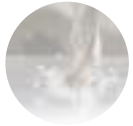
spike Sensory tool holder

0.07	€	Tool costs in € / piece
180	€	Machine-hour rate
45	min	Tool change time / shift
1,500,000	Stk.	Serial number of pieces / year
4,710	€	Saving tool costs in series per year
3,164	€	Savings tool change costs in series / year
7,874	**€**	**Total savings on tool 3H**



tool number	1H-1	1H-2	2H	3H	5V	7V	8V-1	8V-2	9H	11H	12H	13H	14V-1	14
Service life (number of parts)	6,000	6,000	5,000	4,000	3,000	3,000	1,500	20,000	7,000	4,000	7,000	20,000	7,000	50,
Share of tool costs in%	2%	2%	12%	9%	2%	2%	12%	0%	4%	21%	6%	2%	5%	
Optimization of service life	0%	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Tool cost savings in ct / piece	**0.0**	**0.0**	**0.0**	**0.31**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	
Tool change cost savings in ct / piece	**0.0**	**0.0**	**0.0**	**0.21**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	
Total savings in ct / piece	**0.0**	**0.0**	**0.0**	**0.52**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	

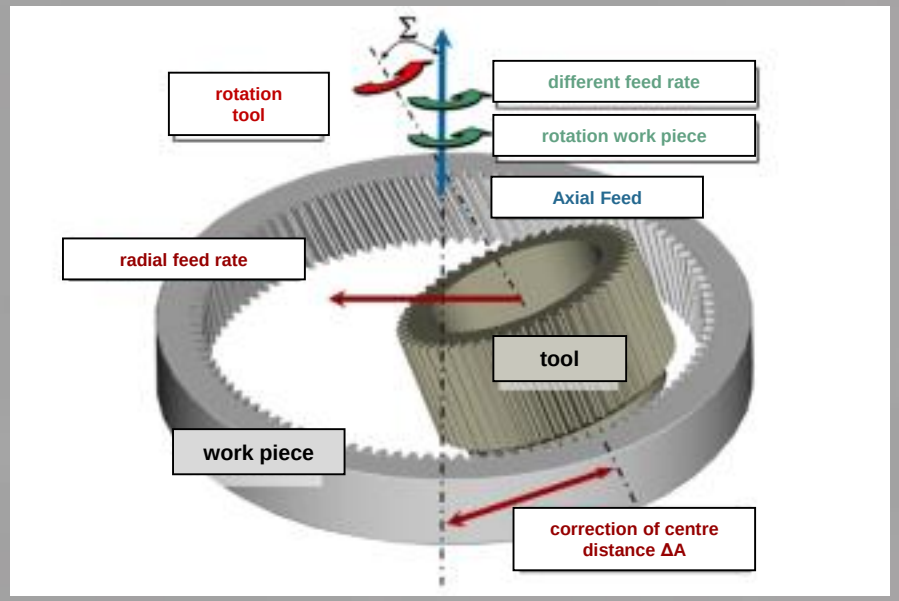


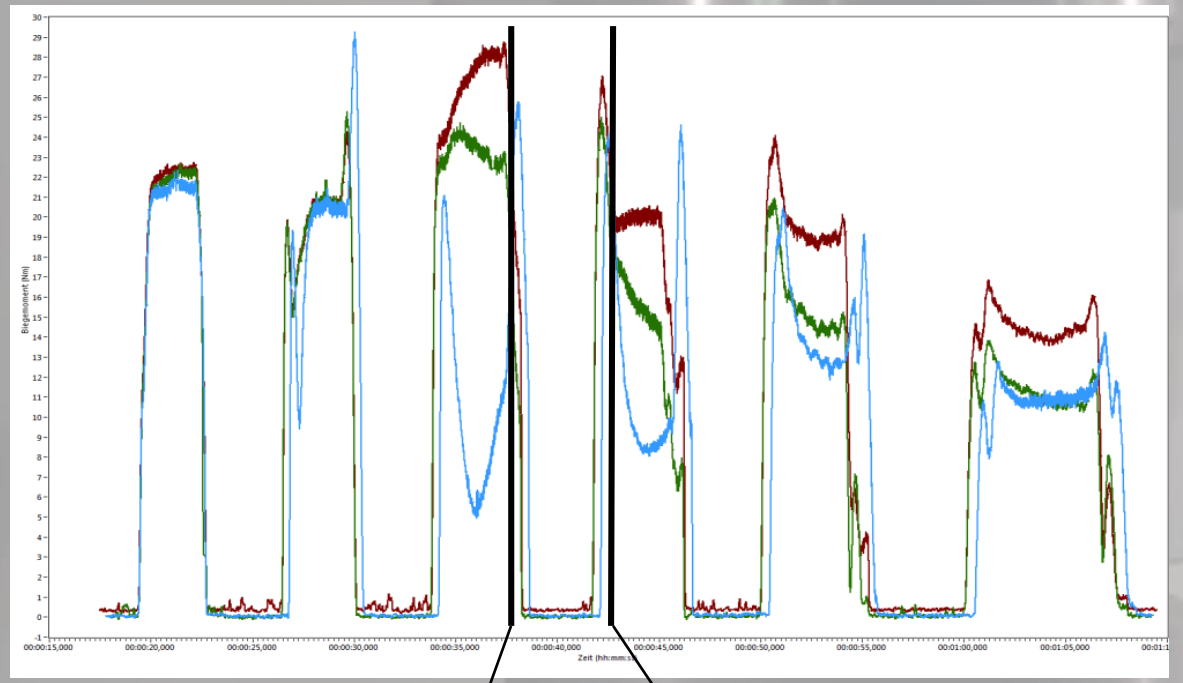


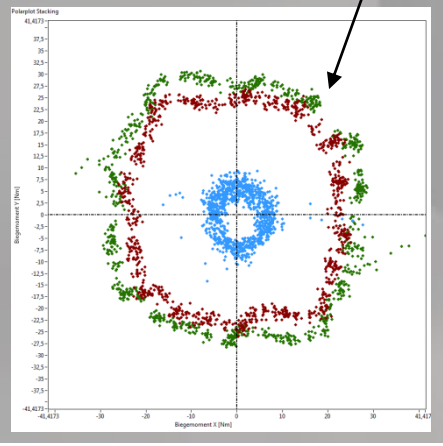


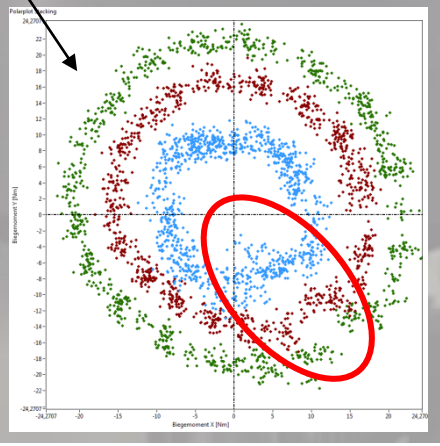


spike® Skiving









Special Features of Skiving:

- Workpiece and tool rotate
- Despite the same parameters, the volume being cut changes with each rotation of the workpiece

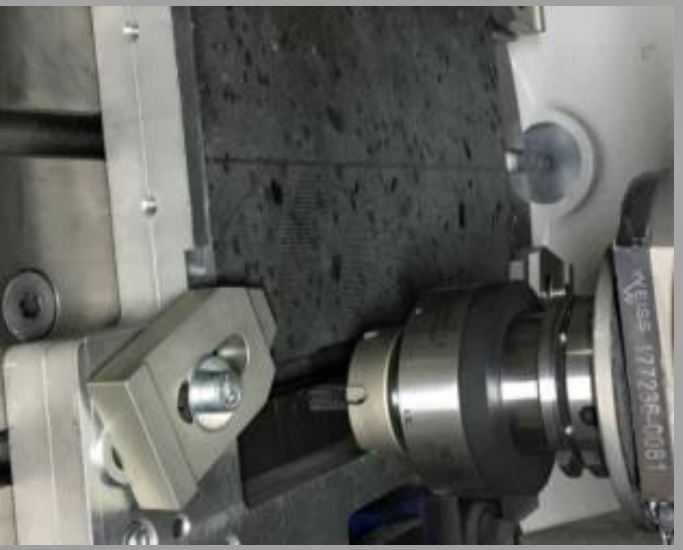
- That's why process histories are so different at first glance (graph)
- However, problems with wear on certain teeth of the tool can be detected (as seen circled in red).

Process analysis and monitoring in CFRP

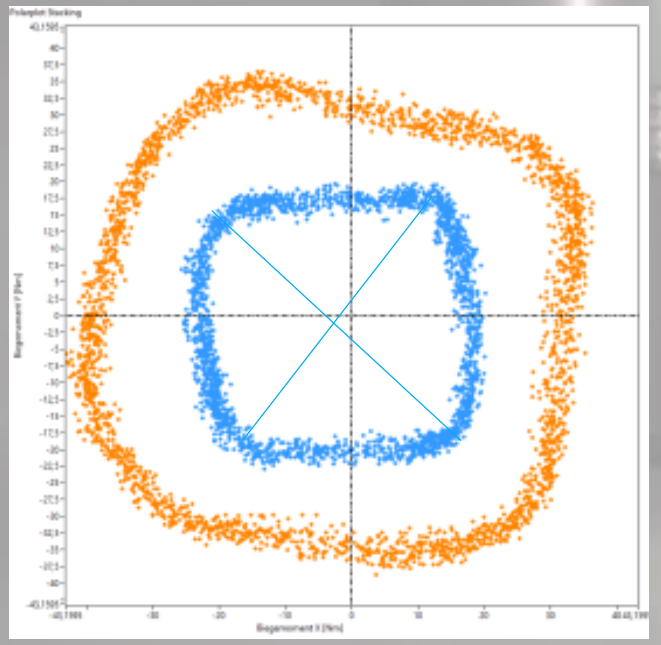
Process analysis CFK – process

- CFRP → high abrasive wear situation
- High process load, aspecially high feed forces lead to delamination → waste because of crack notch (Anrisskerbe)
- Aircraft wing parts → huge parts in small series → clamping pointed → critical for vibrations

Question 1: Can we detect tool wear and position of tool wear/bad quality?



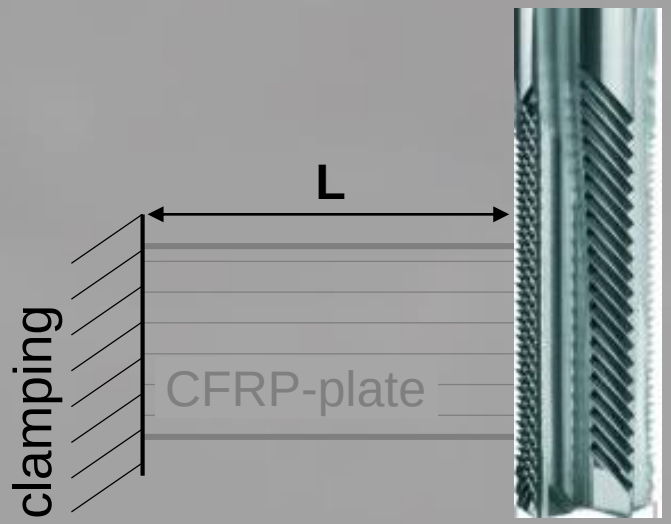
WZ: Ø10mm, 4 cutting edge VHM
WS: 6mm CFRP, multi-directional
Para: a_e = ØWZ , n = 18000 rpm
v_f = 3000 mm/min,
f_z = 0,04 mm

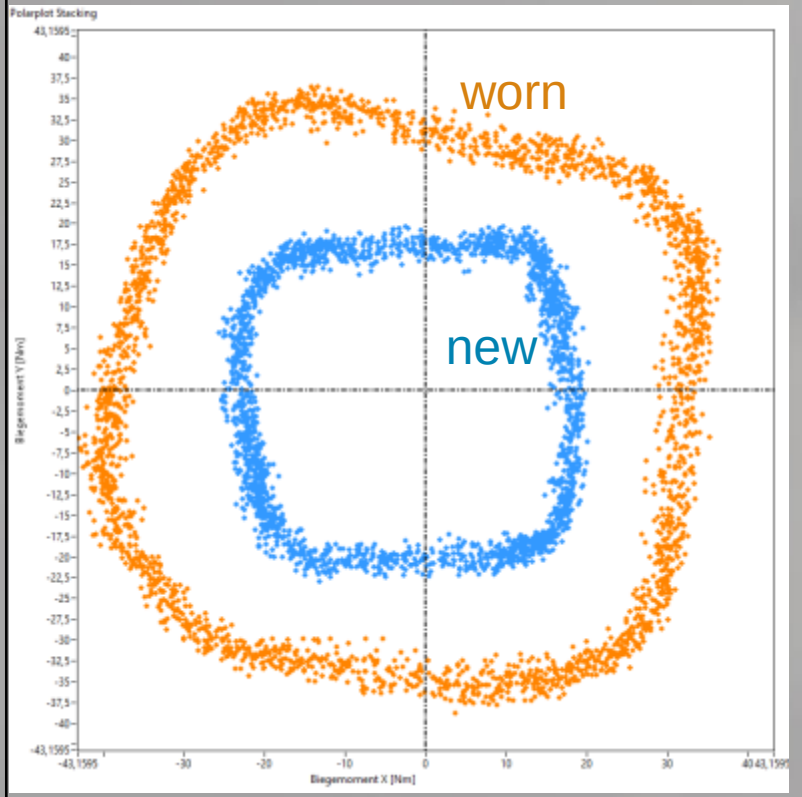
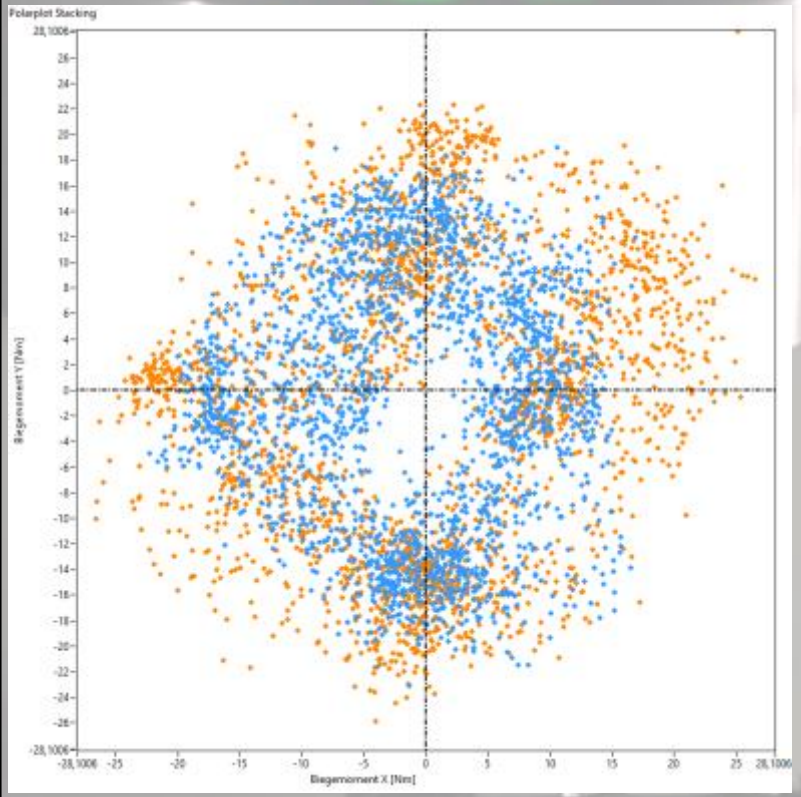


new
→ runs out
0,005 prooved

worn out
→ Double $B_{x,y}$
→ Cutting edge offset

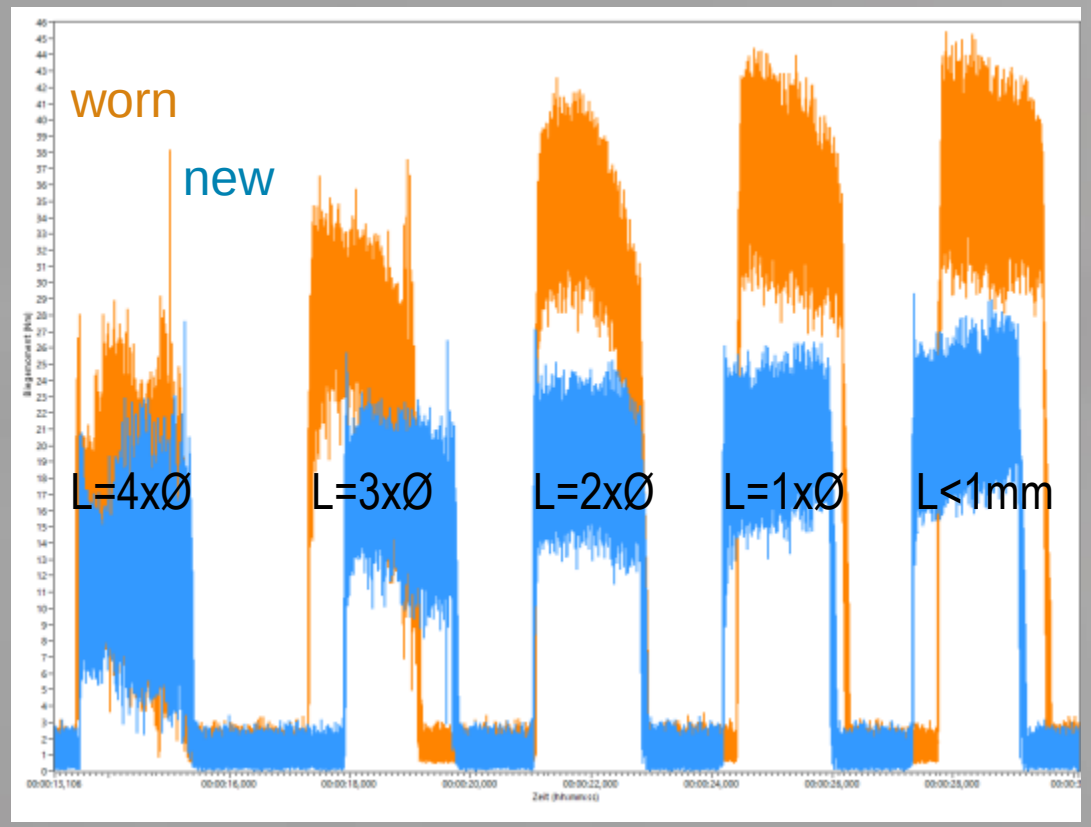
Question 2:
Is it possible to detect critical vibrations of work piece?



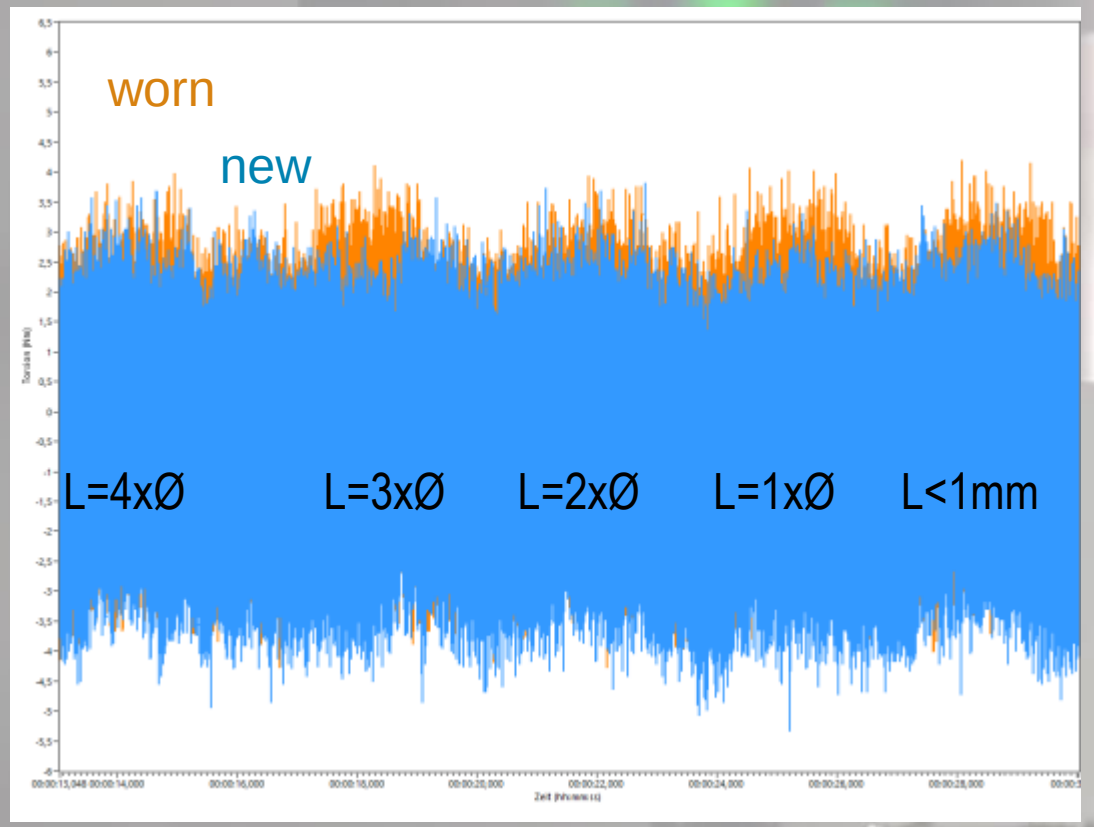
L	L < 1mm	L = 4xØ (40mm)
	Ideal work piece clamping	Not ideal work piece clamping
		
		Critical vibration

Process analysis and monitoring in CFRP

spike® bending moment



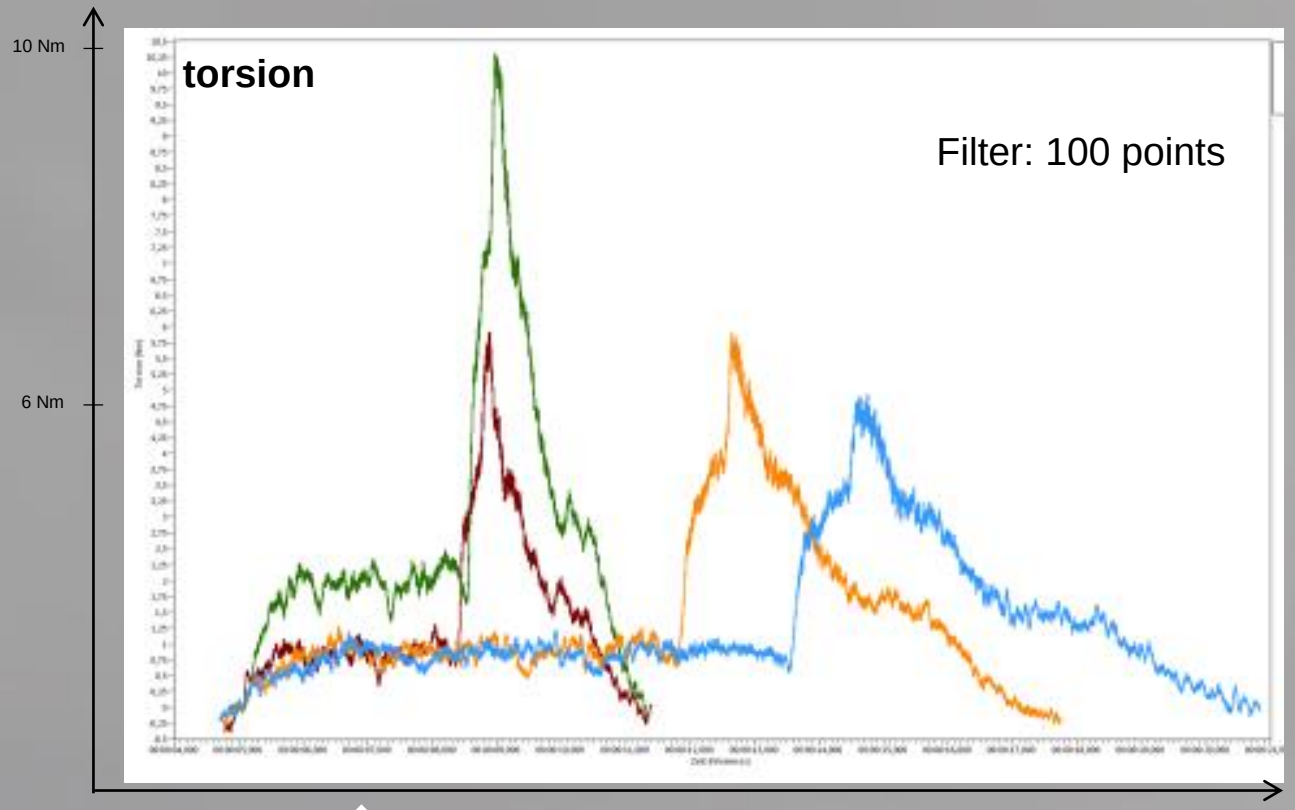
Torque



Approach of process optimization

Optimization approach:

1. Increase of feedrate **0.8** → **1** → **2** m/min
2. Reduction of the torsion by 40% by doubling the speed from 6000 rpm to 12,000 rpm at **2** m/min



process data:

time: 16 sec, 12 sec, 6 sec

Nm_{max}: 4.5 Nm, 6 Nm, 10.5 Nm

Results:

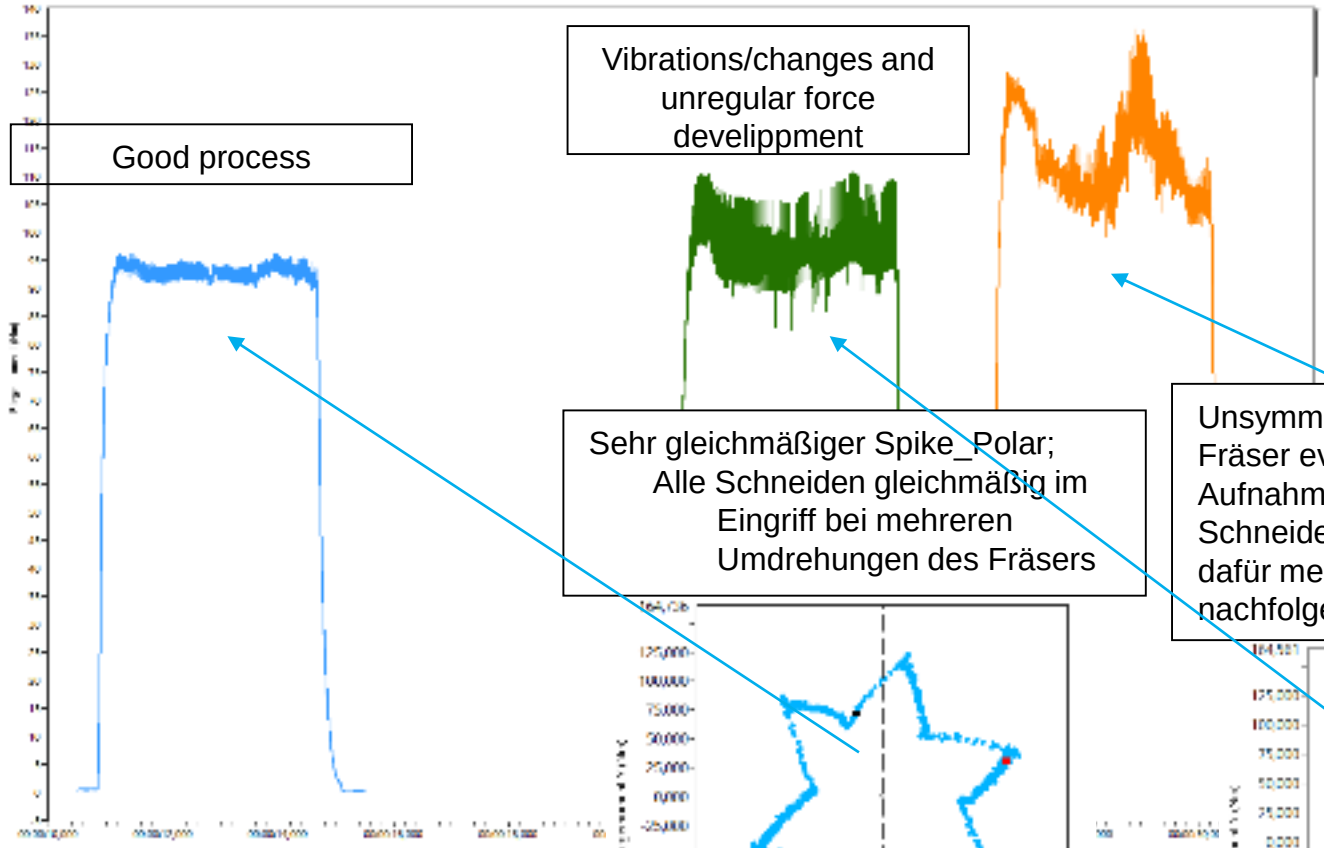
- Reduction of process time by 62% with same torsion
- Identification of potentials of further optimization

Face mill – rotating insert

Vibrations/changes and heavy unregular force development

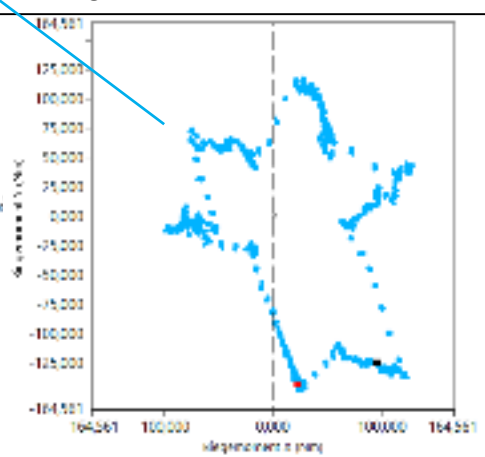
Vibrations/changes and unregular force develippment

Good process

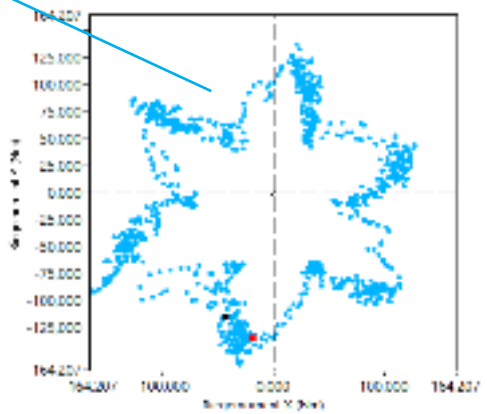


Sehr gleichmäßiger Spike_Polar;
Alle Schneiden gleichmäßig im Eingriff bei mehreren Umdrehungen des Fräsers

Unsymmetrischer Spike_Polar:
Fräser eventuell nicht zentrisch auf Aufnahme gespannt und geklemmte Schneide nur minimal im Eingriff; dafür mehr Materialabtrag auf der nachfolgenden Schneide



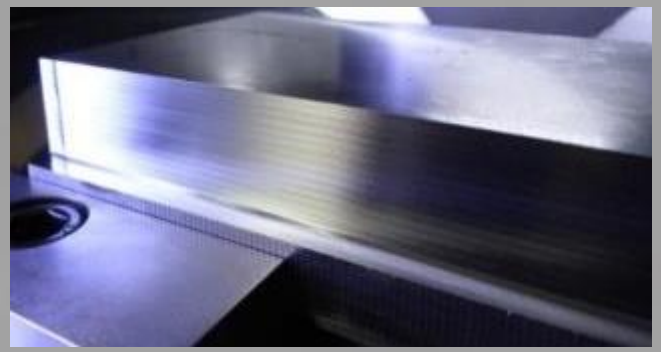
gleichmäßiger Spike_Polar;
Durch den Verschleiß größerer Kraftaufwand; größere Streuung der Messpunkte



Comparison new – clamped – worn – Bend

spike®kpi max. bending moment

Finding core parameters via test trials:



Workpiece:

- Material:
  1.2379 (X155CrVMo12-1)
  (stainless steel carrier cold work tool steel)

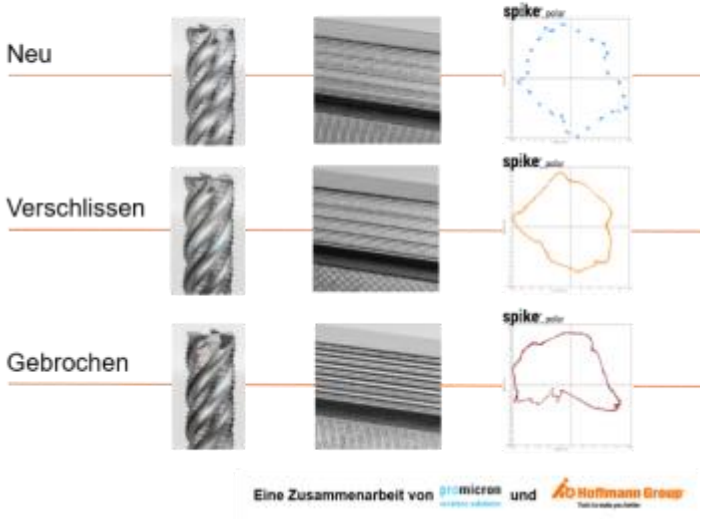
Process parameters:

- Werkzeug: 205550 12
  GARANT Slotmachine
- v_c: 120 m/min
- f_z: 0,061 mm/Z

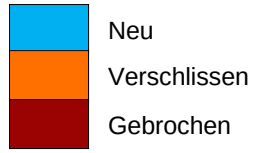
Generic spike®_kpi in tool

spike®kpi Max. bending moment

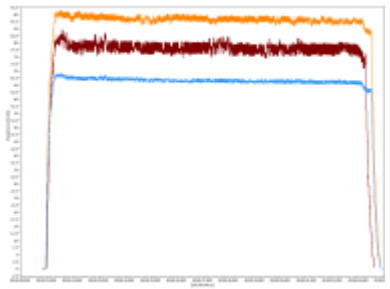
Results of the test trial:



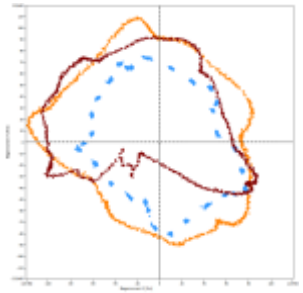
Ergebnisse im Vergleich mit spike® Toolanalyser:



Biegemoment Stacking:



Polar Stacking:

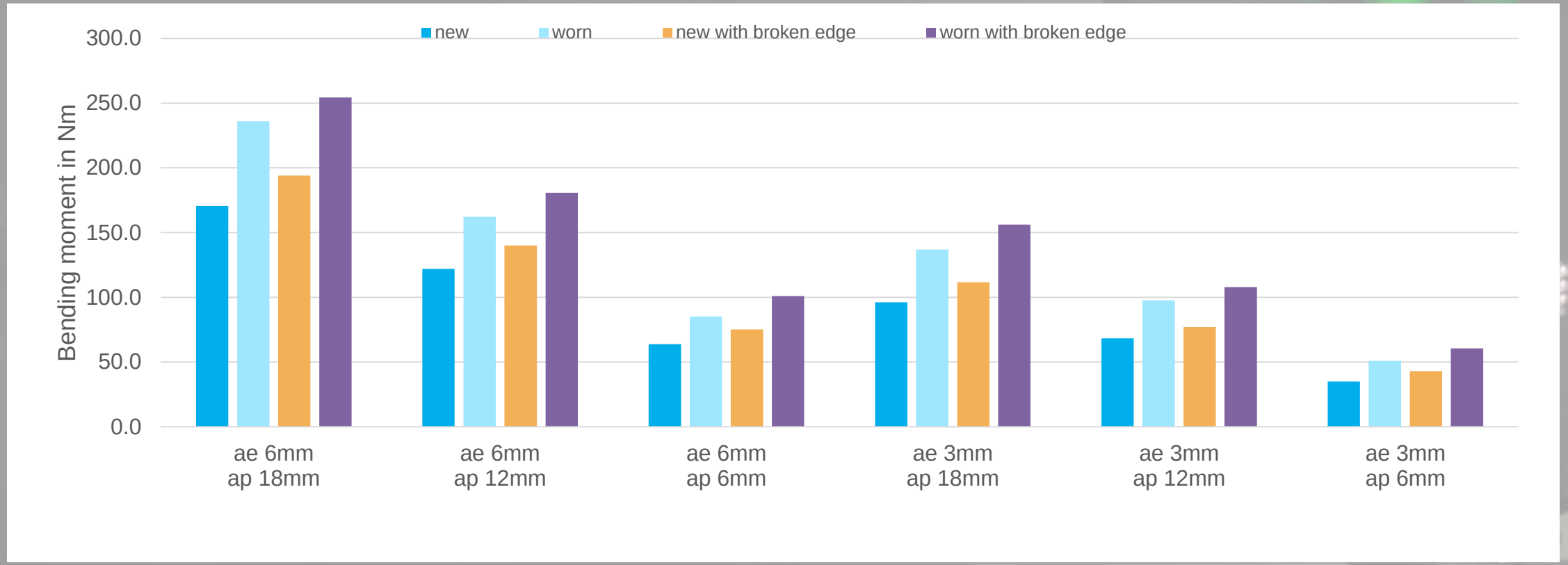


- Broken edge can be detected by spike_polar
- Tool has same bending moment values in worn status
  - ✓ Max.bending moment and therefor end of tool life time can be defined for this concrete process

A cooperation of promicron wireless solutions and Hoffmann Group

Is max. bending moment always the same?

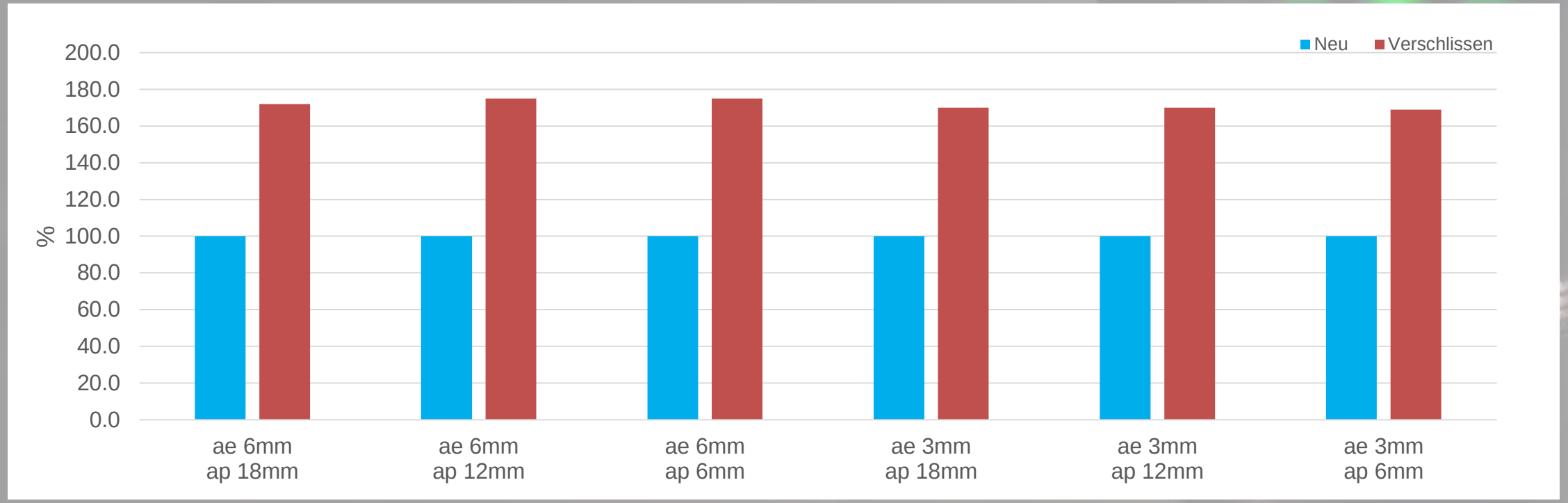
Results of different test trials:



A cooperation of promicron wireless solutions and Hoffmann Group

Is max. bending moment always the same?

Bending moment in % in comparison of „new vs. worn“:

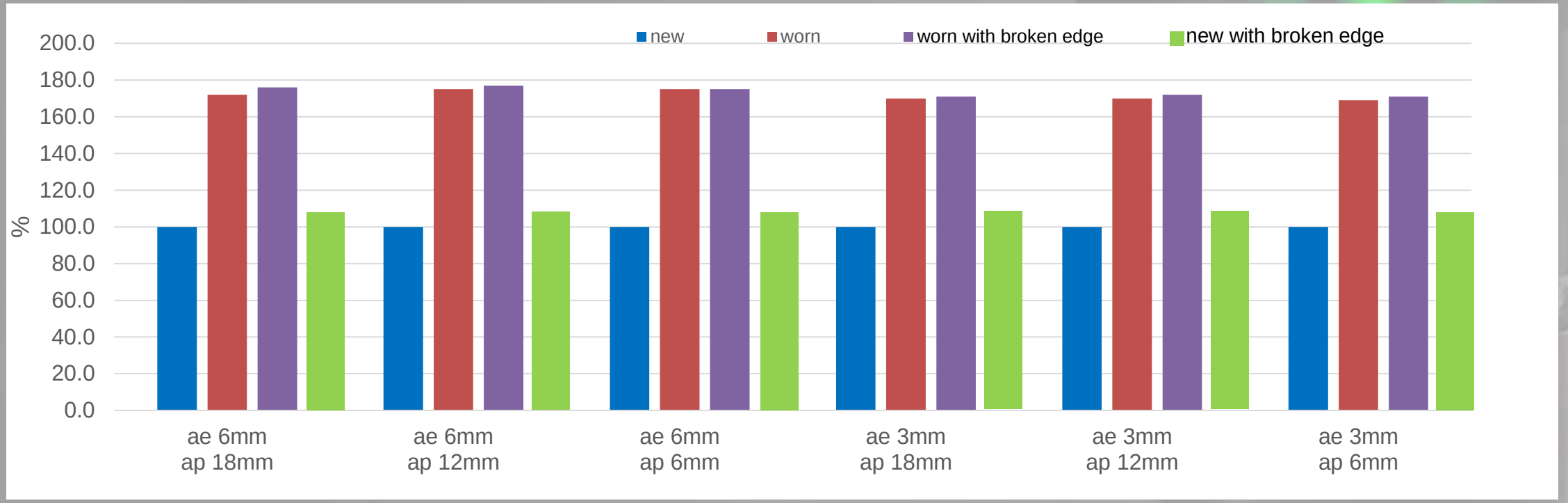


- Max. scattering in bending moment is 6%
- Max. bending moment is linear for different parameters (ap/ae)

A cooperation of promicron wireless solutions and Hoffmann Group

Needs of spike®kpi cutting edge symmetry

Bending moment in % for comparison of „new vs. worn vs. broken edge“:



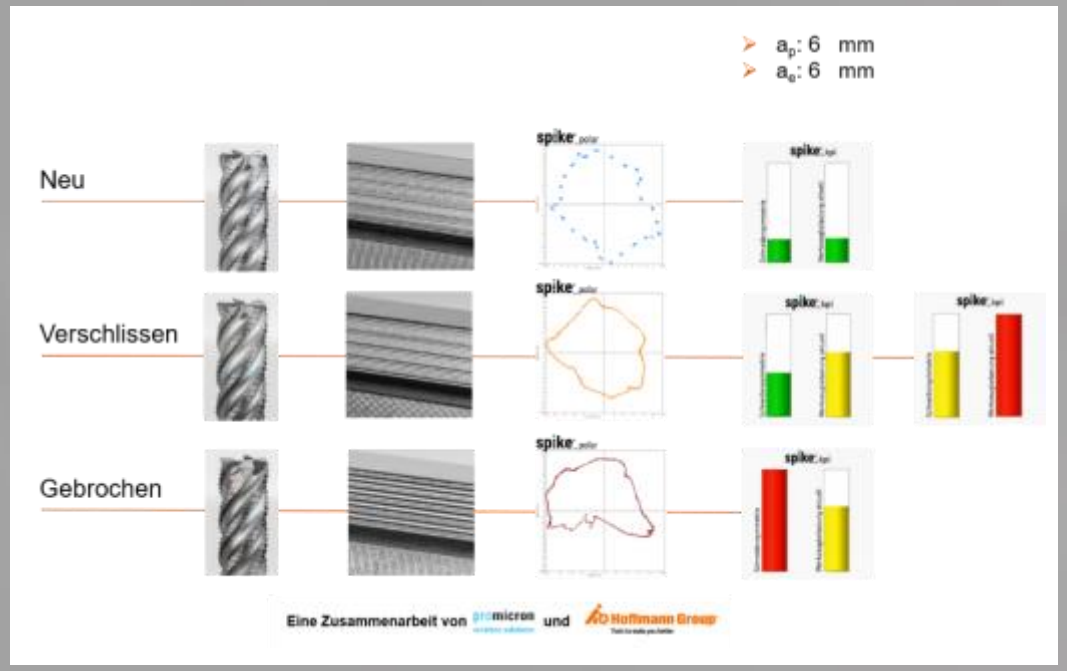
- Max. bending moment is not enough to detect cutting edge brakage! (+/- 1% BM)
- Only with spike®_kpi symmetry broken cutting edge can be detected!

A cooperation of promicron wireless solutions and Hoffmann Group

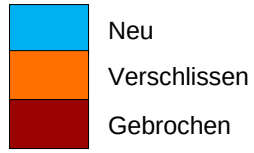
Generic spike®_kpi in tool

spike®kpi Max. bending moment

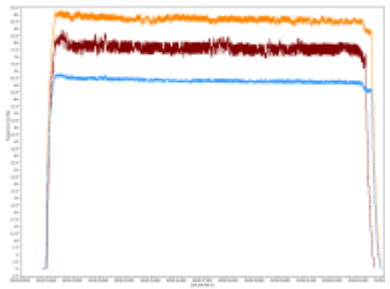
Results of the test trial:



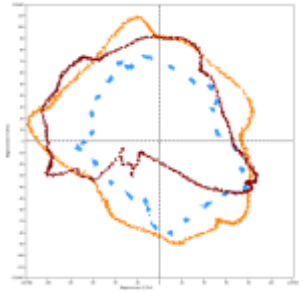
Ergebnisse im Vergleich mit spike® Toolanalyser:



Biegemoment Stacking:



Polar Stacking:



- Broken edge can be detected by spike_polar
- Tool has same bending moment values in worn status
  - ✓ Max.bending moment and therefor end of tool life time can be defined for this concrete process

A cooperation of promicron wireless solutions and Hoffmann Group

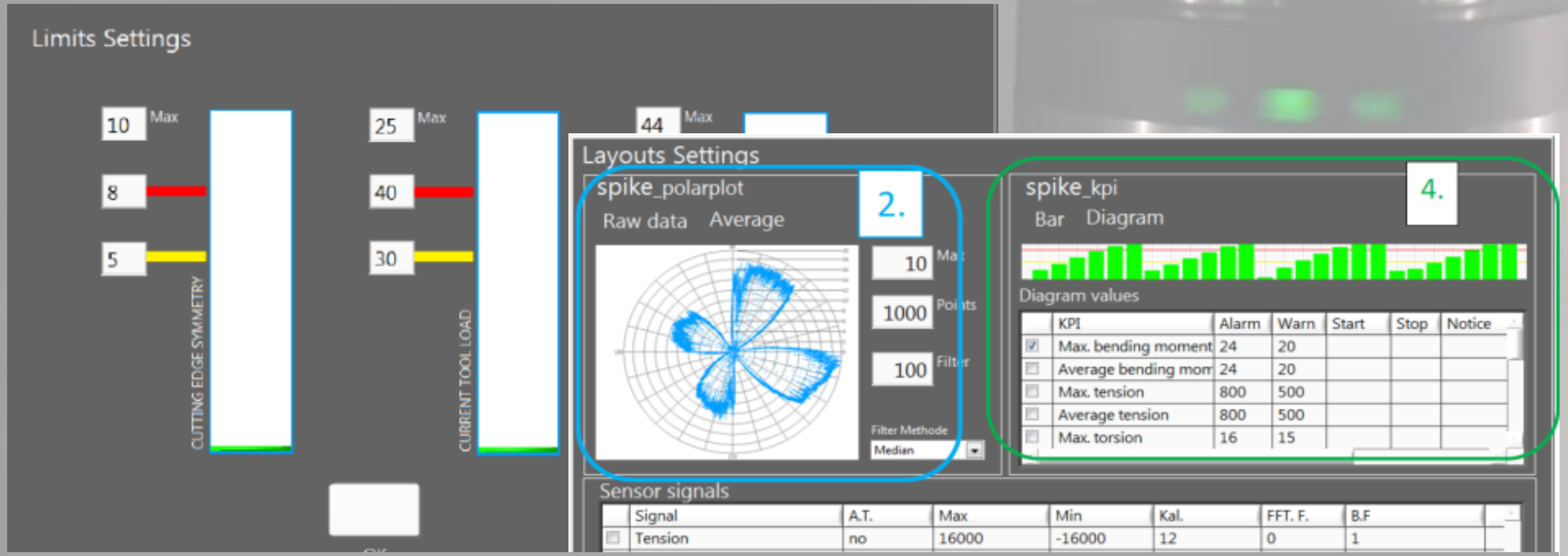
Where do you get these values?

- spike®kpi Max. bending moment und spike®kpi symmetry will be shown soon in the Toolscout software as reference :

Merkmale	Schnittdatenanzeige
Nasswert	
Werkstoff /Werkstoffgruppe	1.2379
Eingriffsbreite ae [mm]	6
Schnitttiefe ap (bezogen auf einen Schnitt)[mm]	6
Schnittgeschwindigkeit Vc [m/min]	110
Drehzahl n [1/min]	2920
Vorschub f [mm/U]	0,4
Vorschub je Zahn fz [mm]	0,08
Vorschubgeschwindigkeit vf [mm/min]	1170
Schnittleistung Pc [kW]	2,764
Drehmoment Md [Nm]	9,046
Hauptzeit th [min]	–
spike®kpi Max.Biegemoment [%]:	67,00
spike®kpi Schneidensymmetrie [%]:	186,00

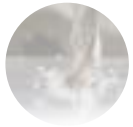
spike® Tool Control Center

promicron wireless solutions



Main goals:
- Monitoring of plan and real values
- Visualize force and kpi offset in % (offset from new tool in %)





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spike® spike®_KPI calculation

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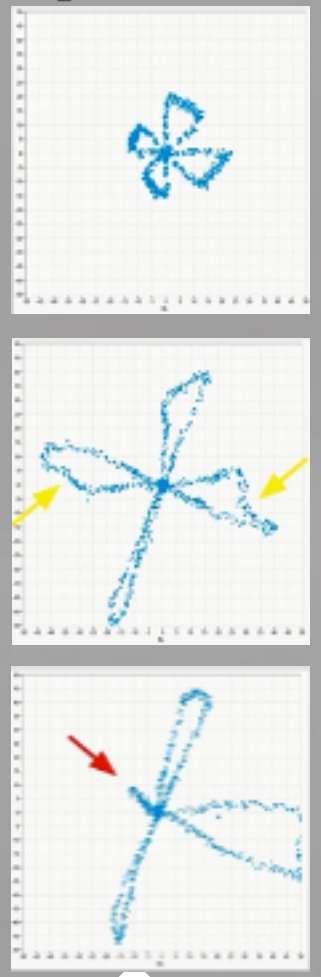
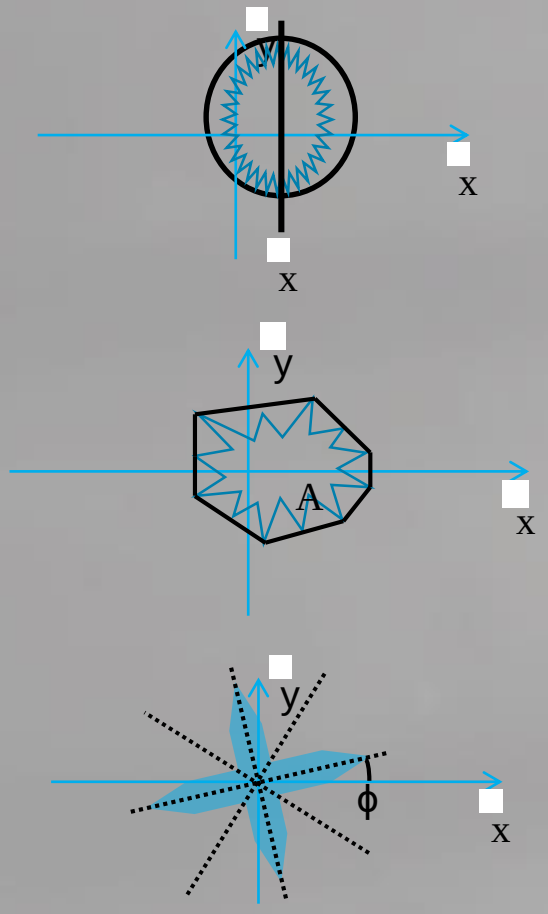
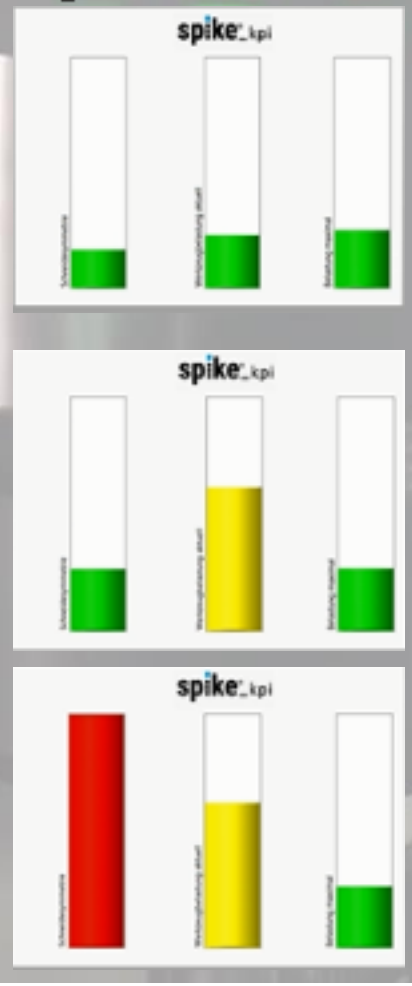
spike®_polar



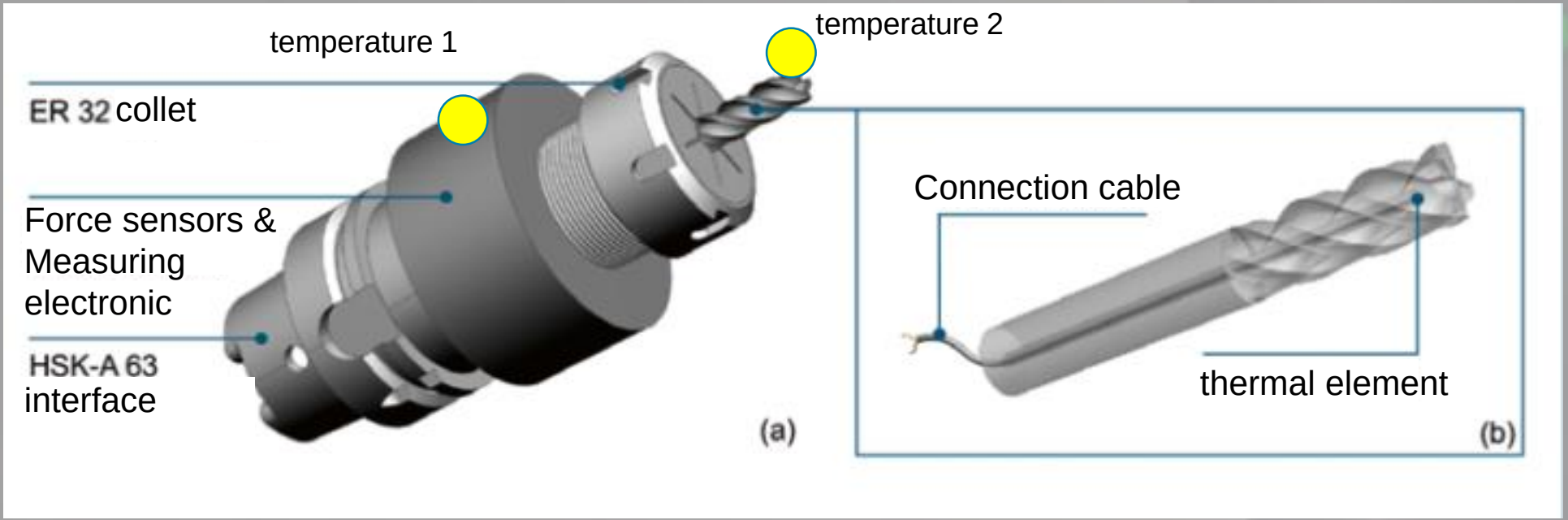
spike® algorithmus



spike®_kpi

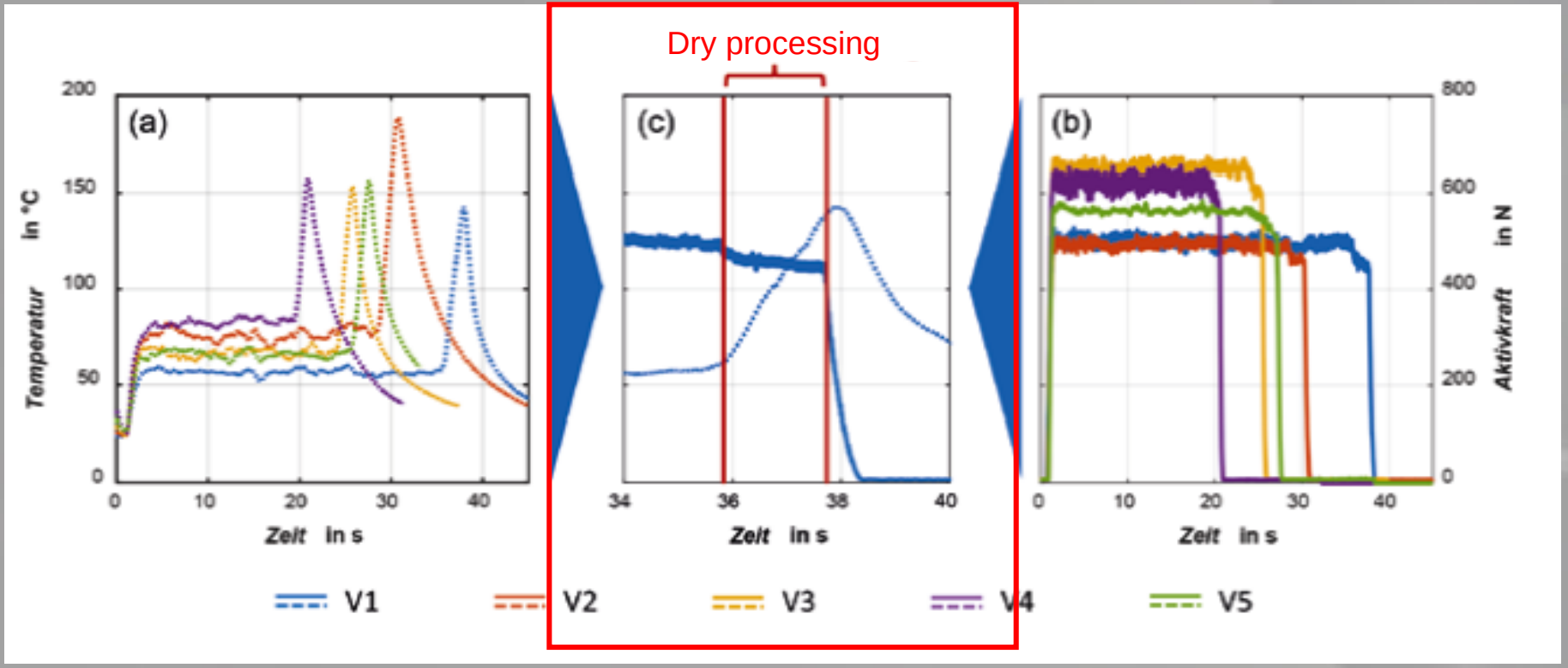


Temperatur on the peak of the tool



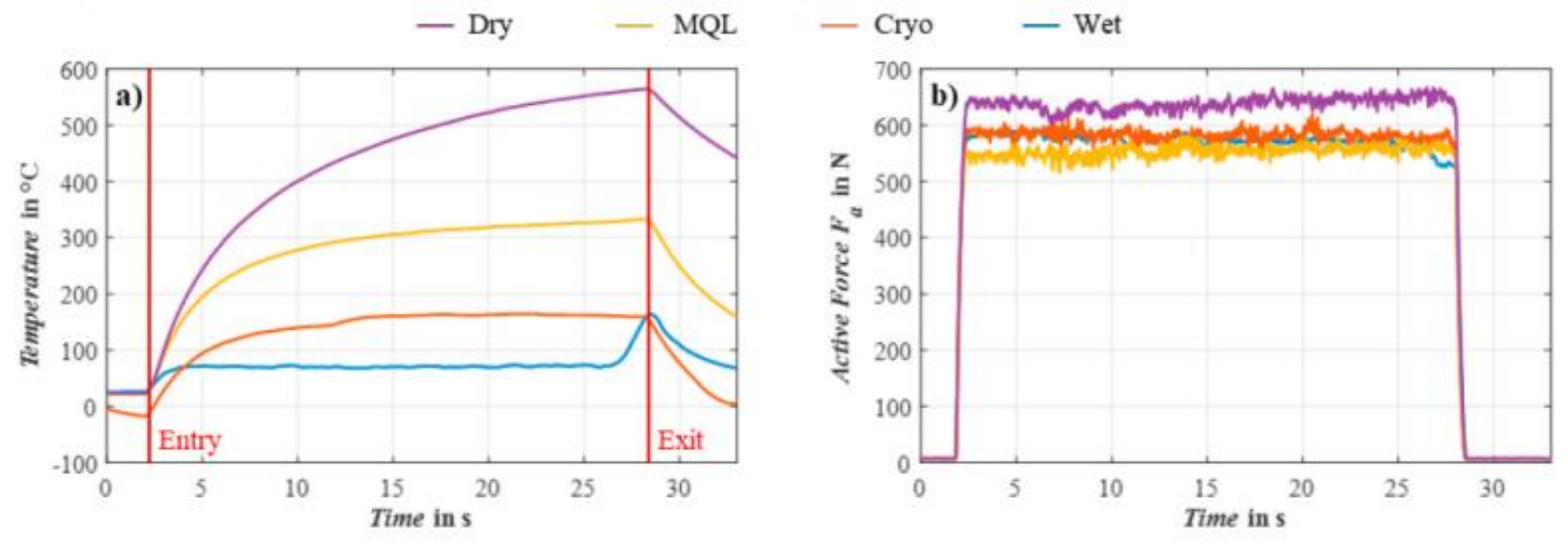
Sensory tool holder spike® (a) and sensor integrated tool (b)

Temperatur on the peak of the tool



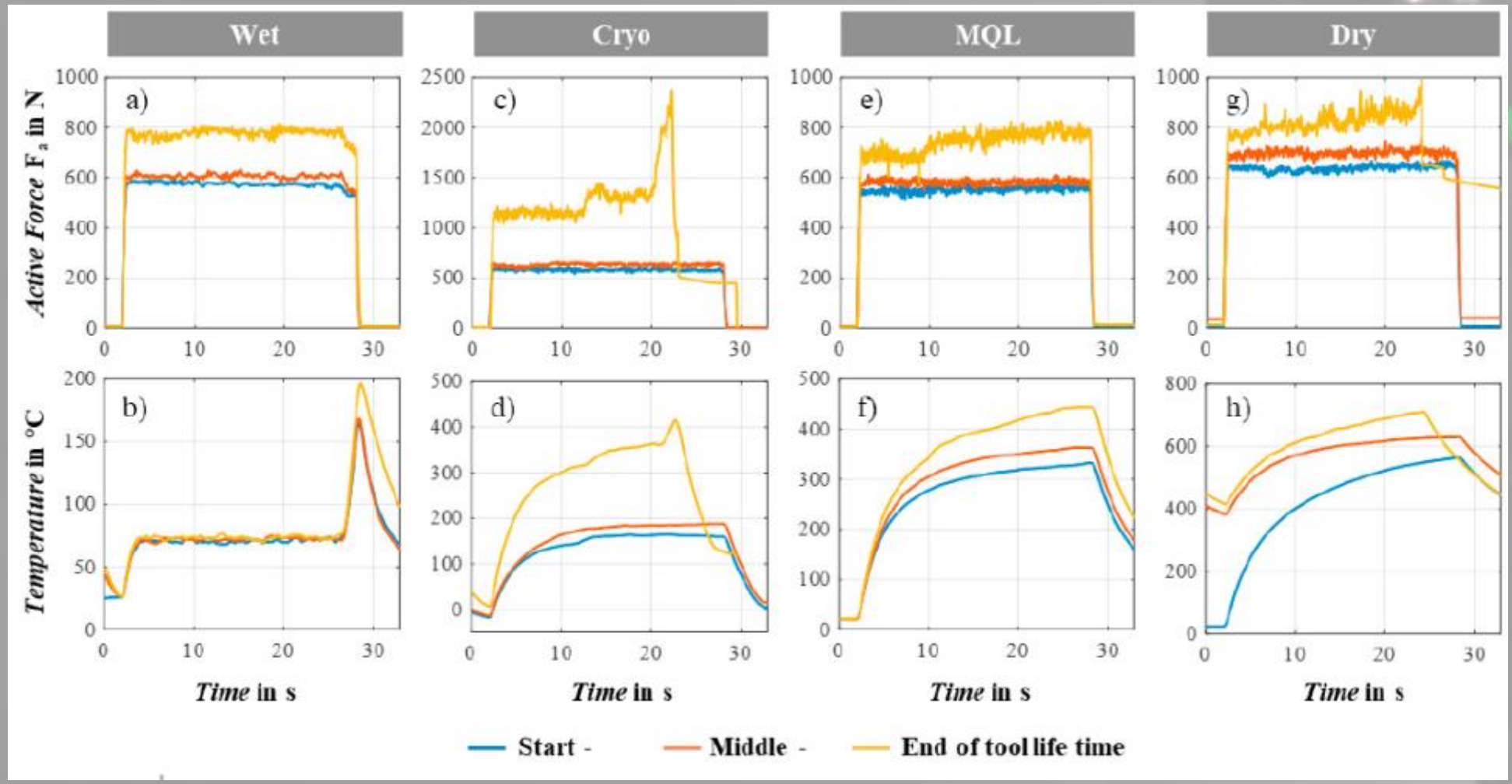
(a) Temperatur profil (b) bending moment profil
(c) Temperatur- and bending moment profil of V1 in the area of dry cutting

Temperatur on the peak of the tool



(a) Comparison of tool core temperature profile with new tools;
(b) Comparison of active force profiles with unused tools

Temperatur on the peak of the tool



Summary of tool core temperature and tool active force over tool life time

spike® Drilling / Rubbing

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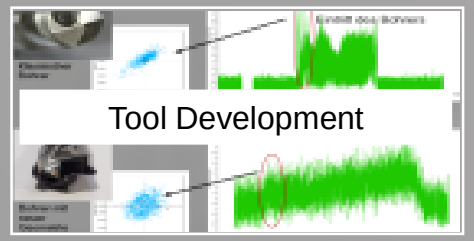
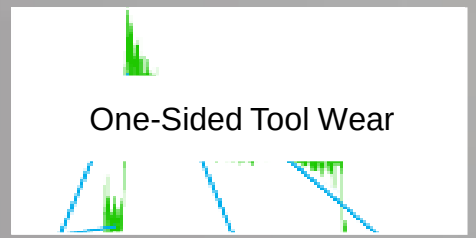
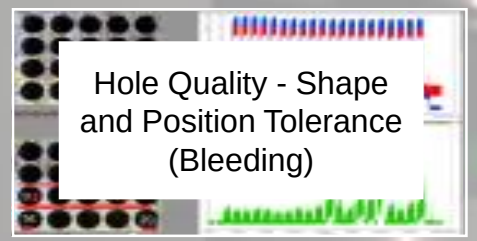
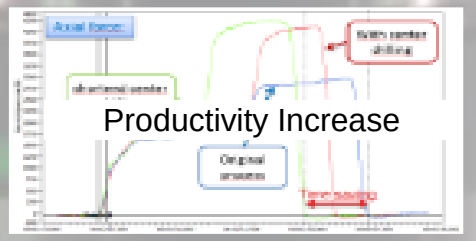
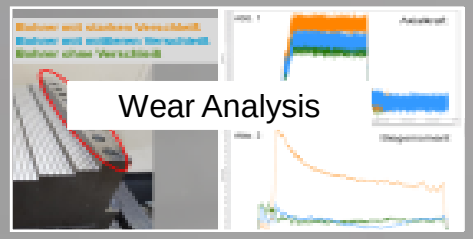
DRILLING/
RUBBING

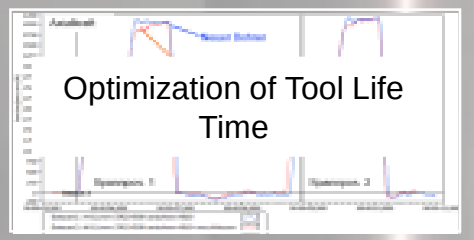


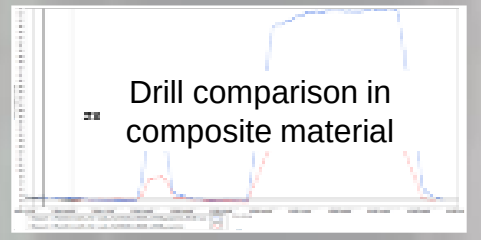


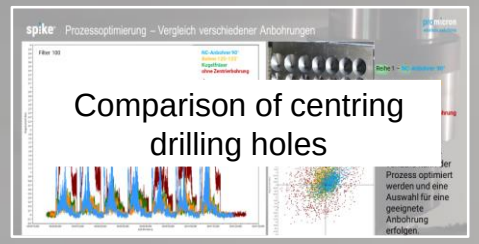


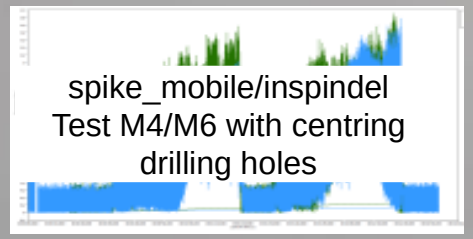


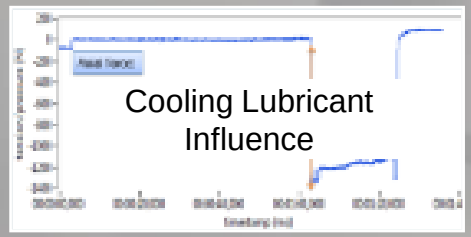




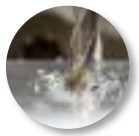














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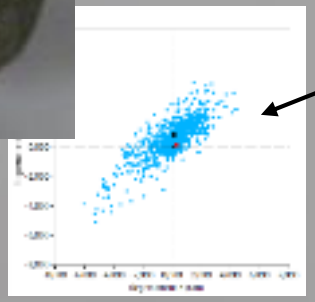
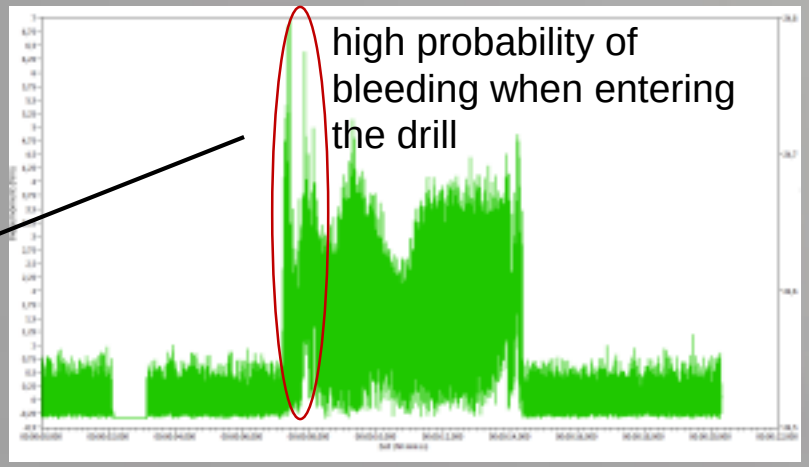
spike® spike®_polar influence of the cross cutting edge

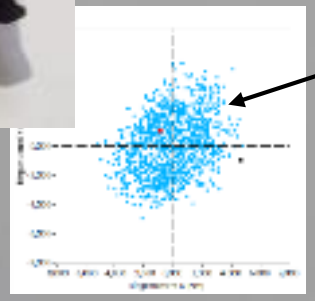
classic drill

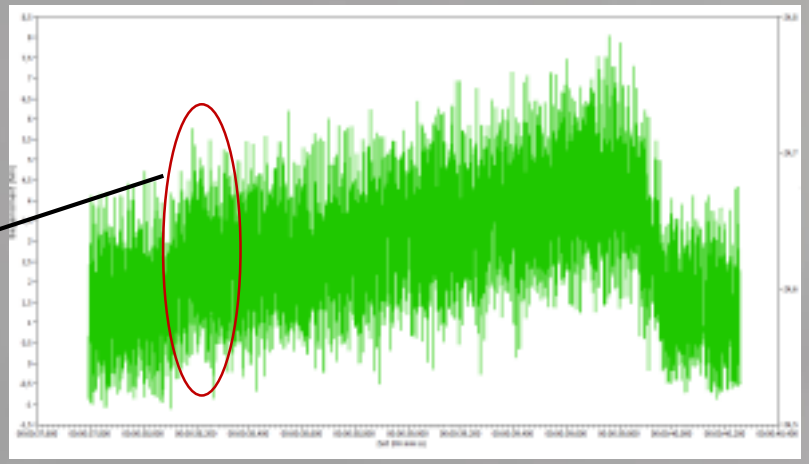




bending moment

drill with new geometry

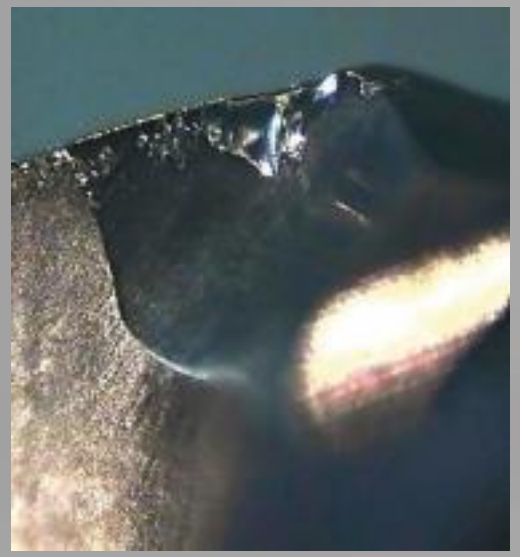


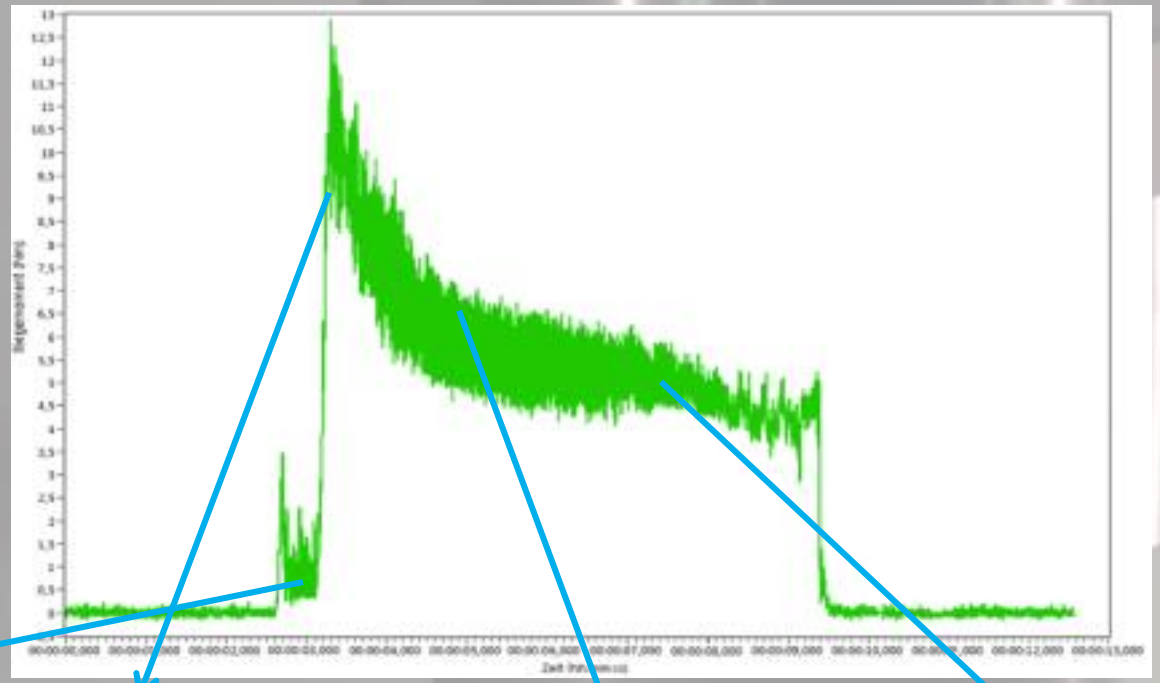


Result:

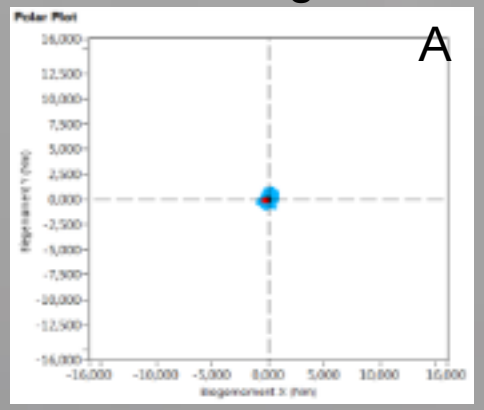
- The bending moment shows the lateral load on the drill and also the quality differences of the drill hole
- The classic drill with a crosscutting had a significantly higher probability of being immersed in the material
- The new geometry of the drill resulted in a straight dipping of the drill, resulting in a better quality borehole

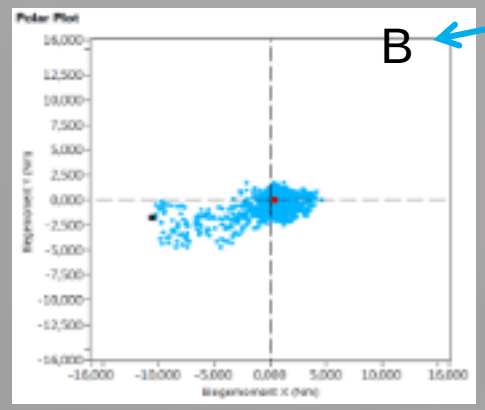
spike® spike®_polar one-sided wear

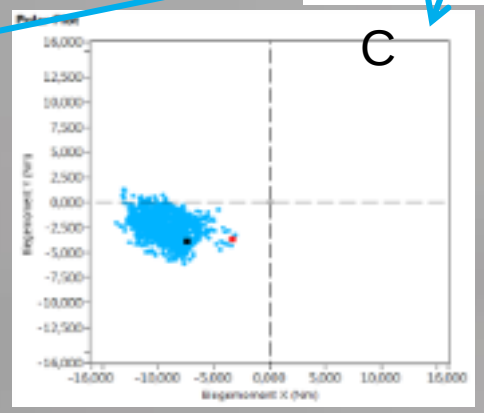


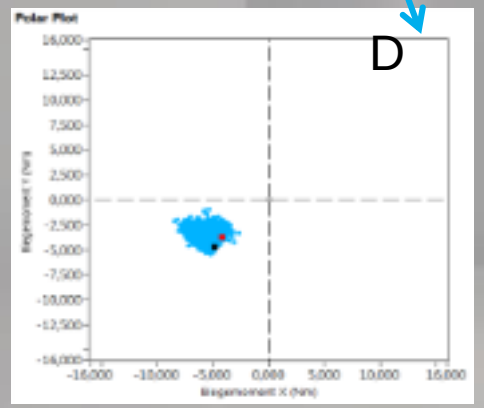


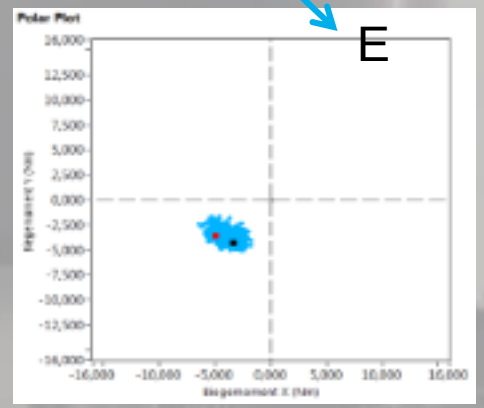
before editing











spike® Course of the drill and borehole quality

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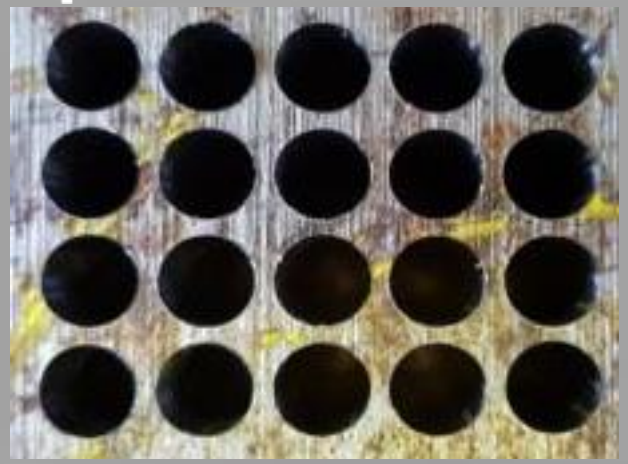
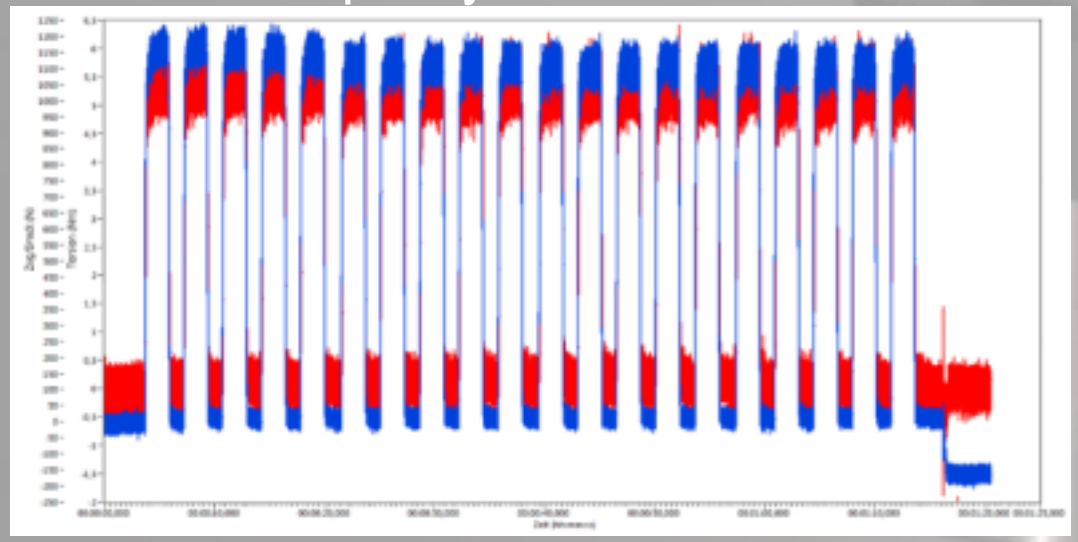
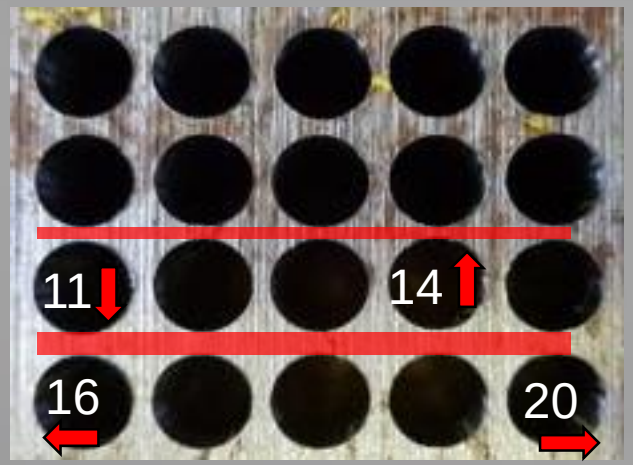


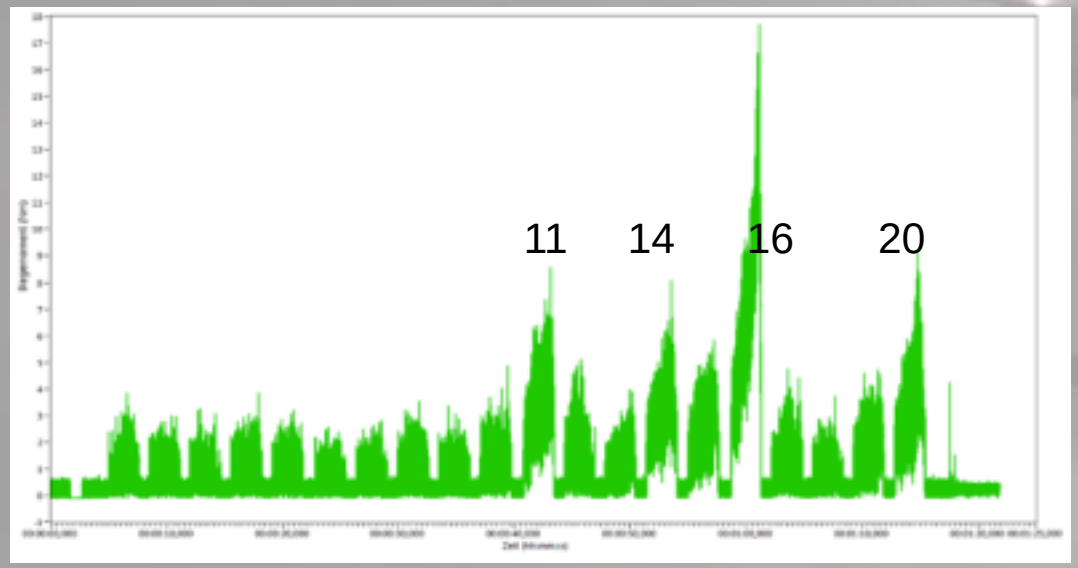
Drill entry



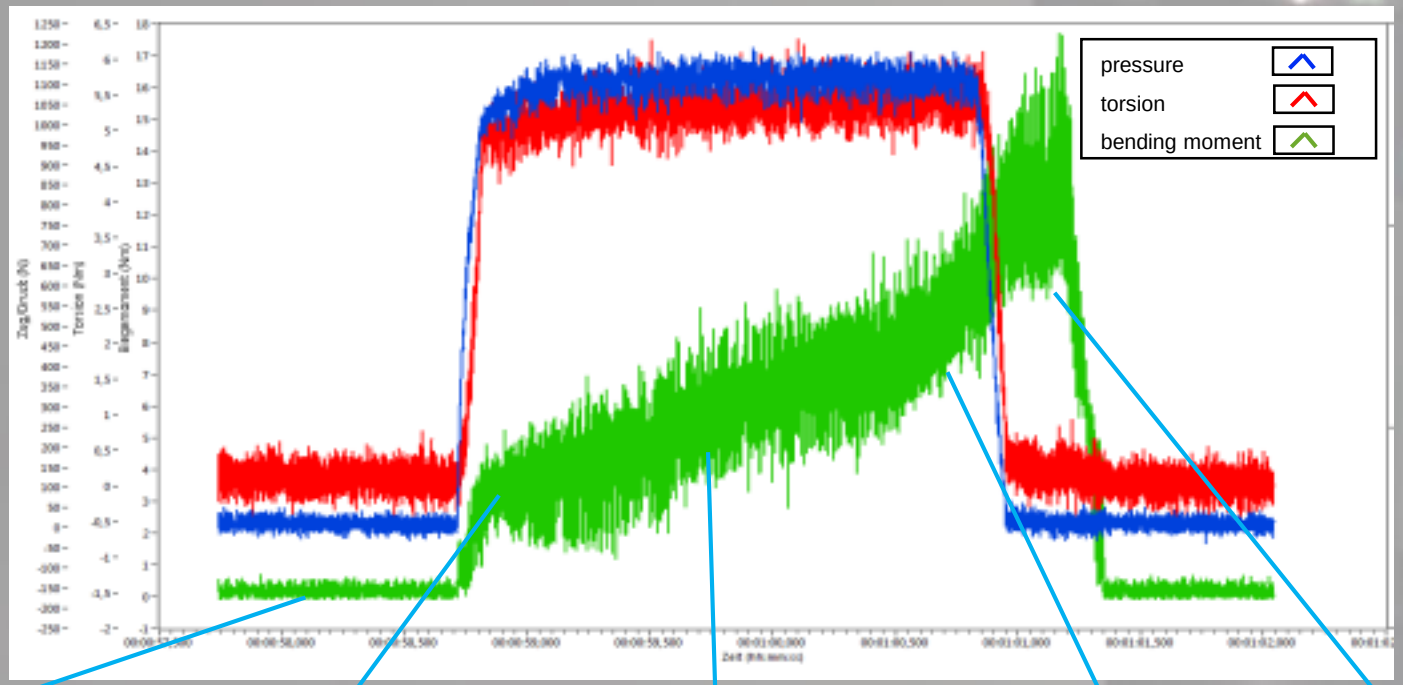
pressure
torsion
bending moment

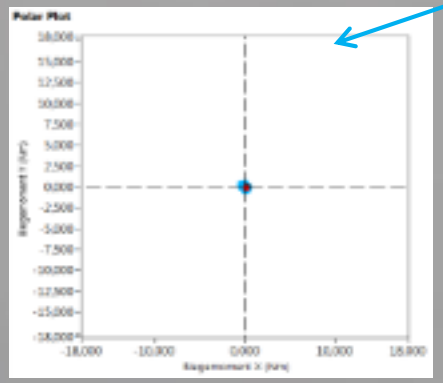


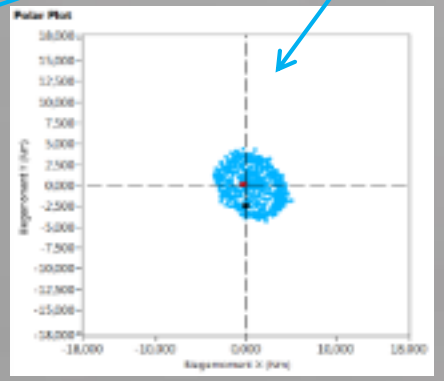
Drill exit

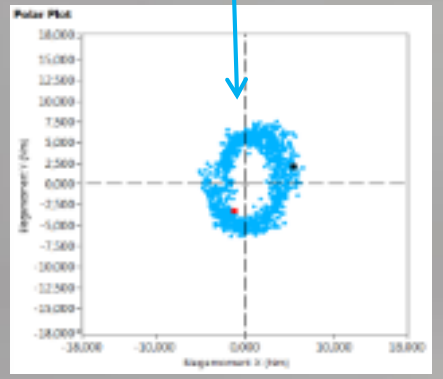


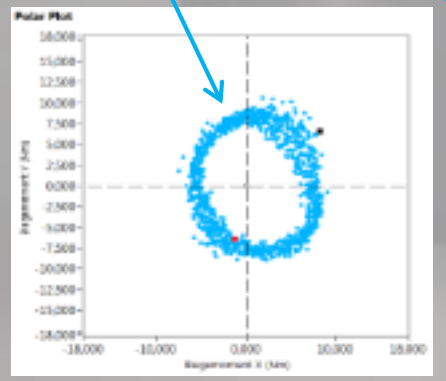
Course of the drill and borehole quality

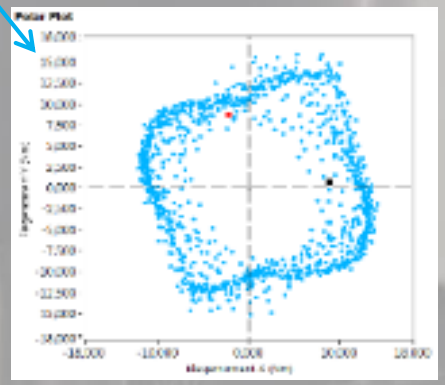




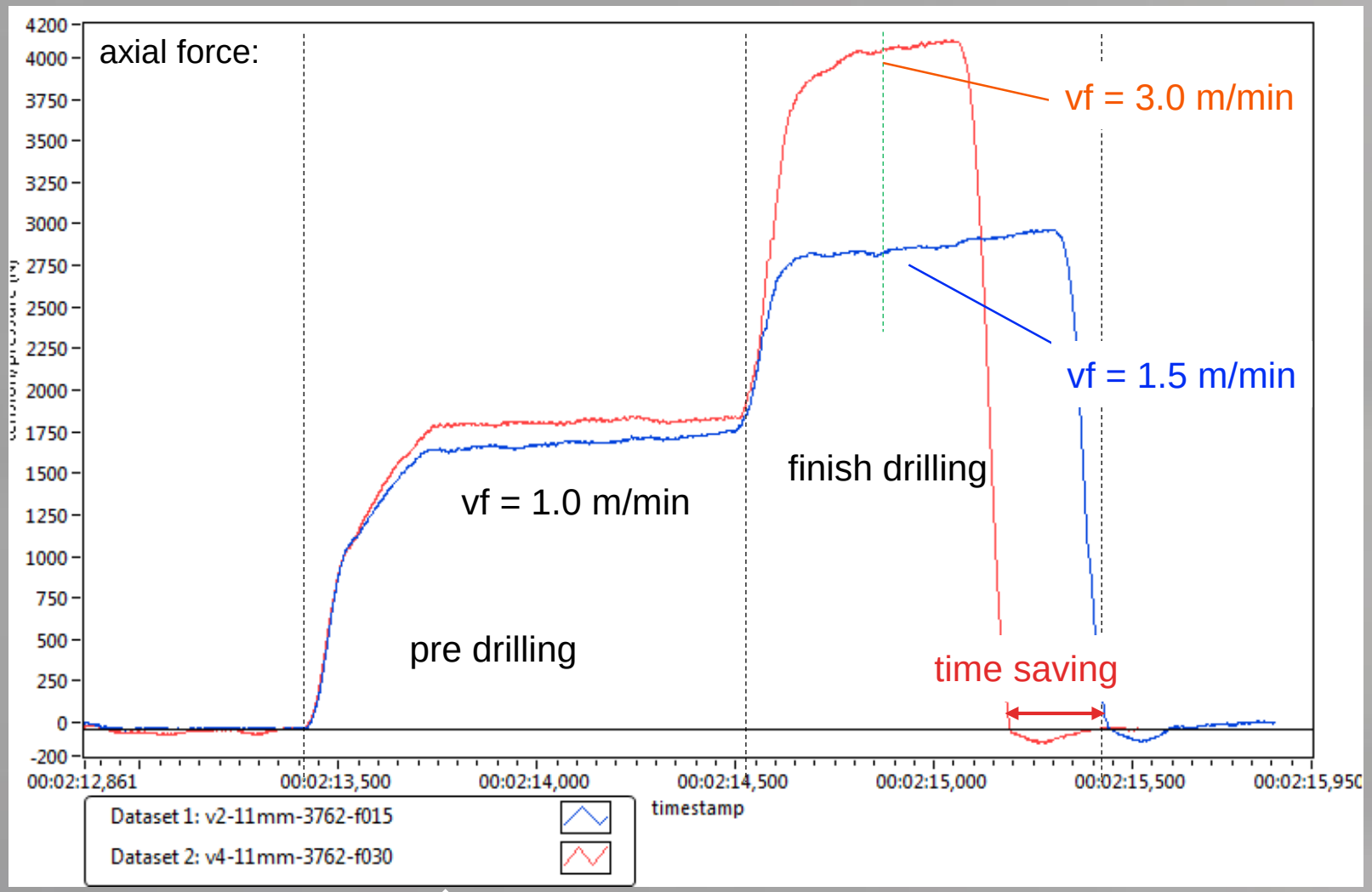








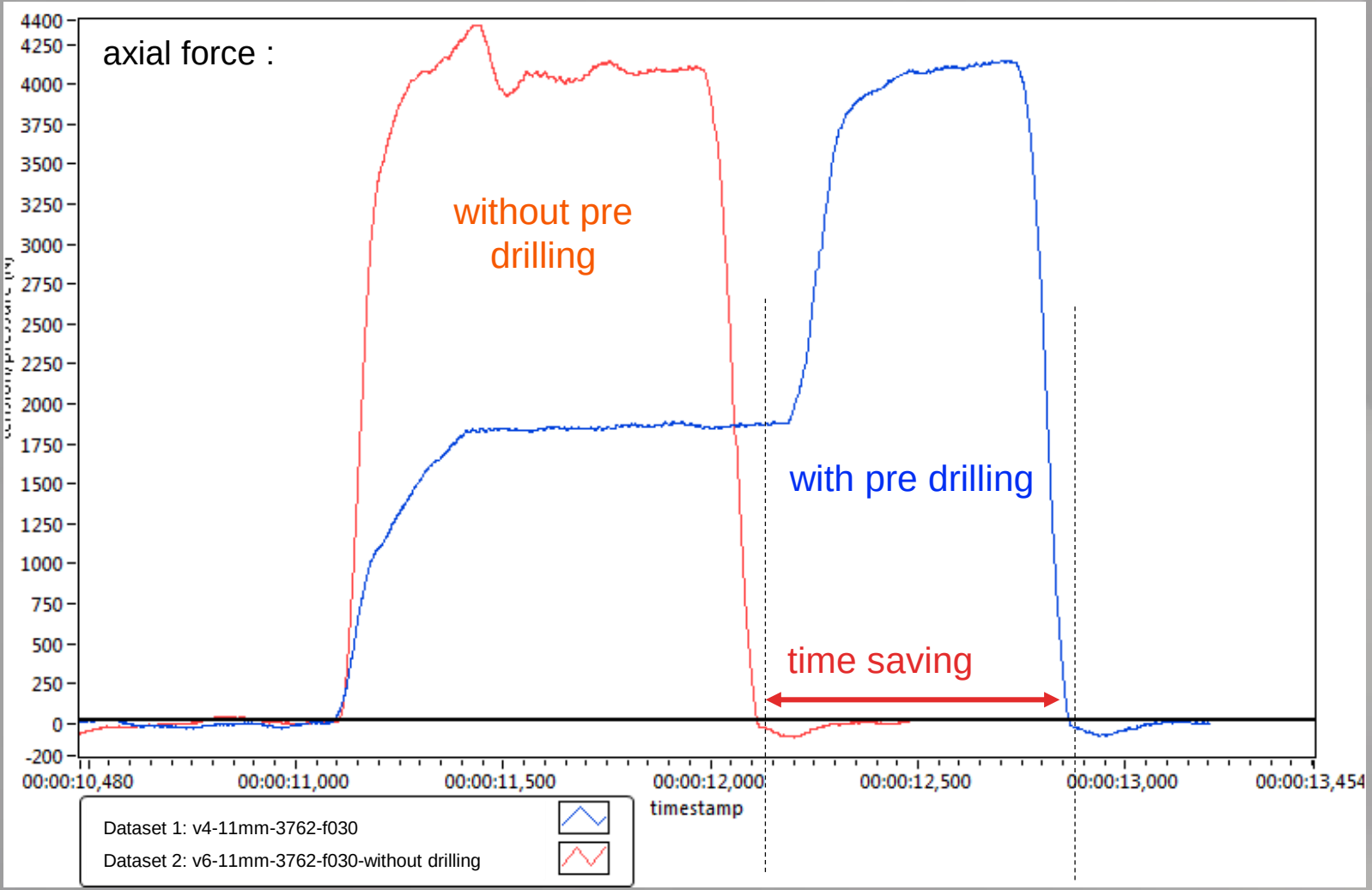
Productivity increase – doubling of feed?



Potential for savings recognizable:

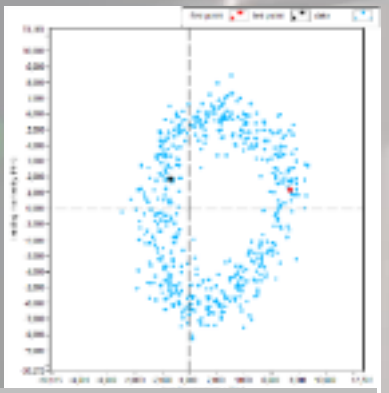
- Doubling of feed means only increase of 30% in axial force
- Time saving:
  0.25 sec / drill

Productivity Increase – Pre drilling useful?



with pre drilling

without pre drilling

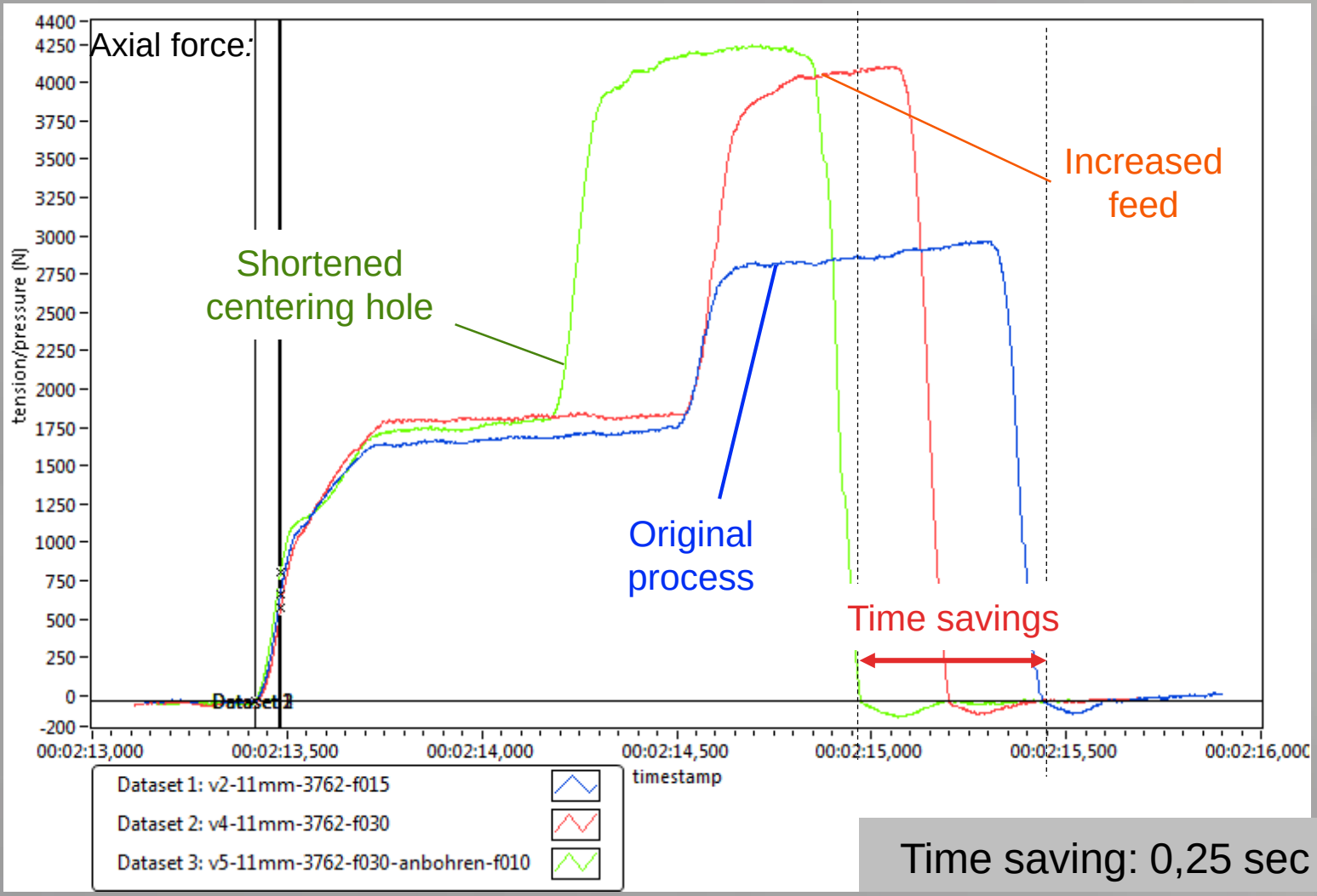


Result:

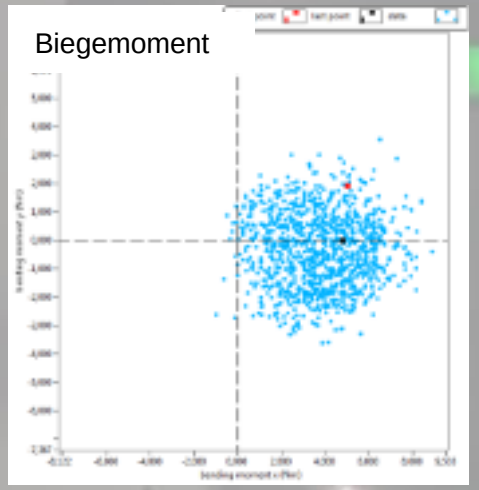
- ☑ Time saving:
  0.76 sec / drill
- ☒ spike_polar shows a circle

- Hole is not exactly centric anymore
- Hole is not exactly centric anymore

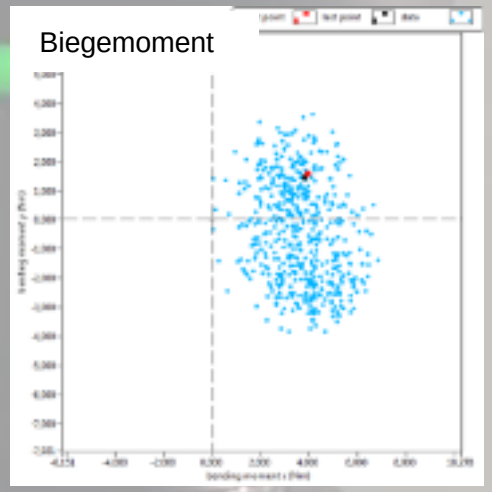
Increasing productivity – does shortening the centring hole makes sense?



with centring



shortened centering hole



Result:

- ☑ spike_polar shows no sideways avoidance.
- ➔ Centring can be shortened

Time saving: 0,25 sec + 0,22 sec = 0,47 sec (23 % process time)

Wear analysis

Drill with heavy wear
Drill with medium wear
Drill without wear

Material:
42CrMo4
Drill: DIA 10
ap: 20
Vc: 80
F:0,07

Fig. 1 axial force

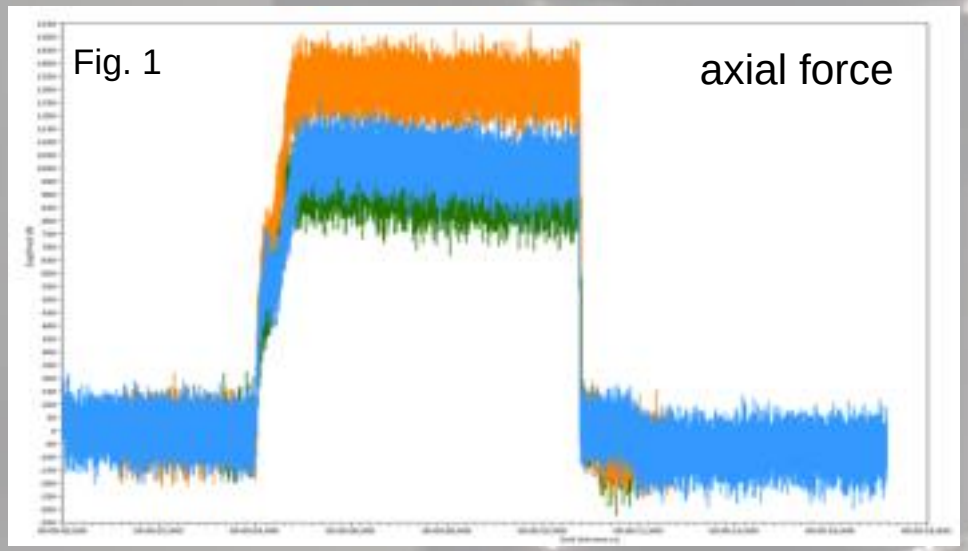
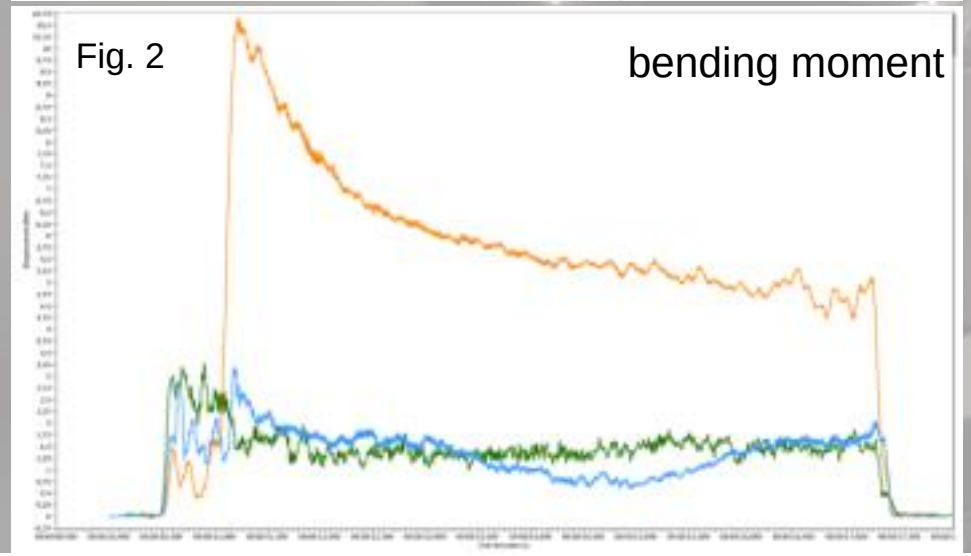
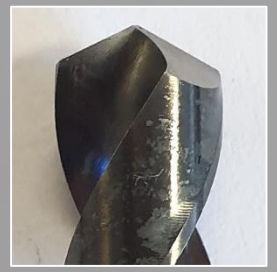
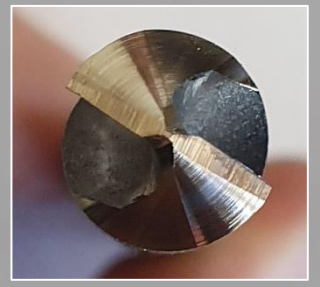
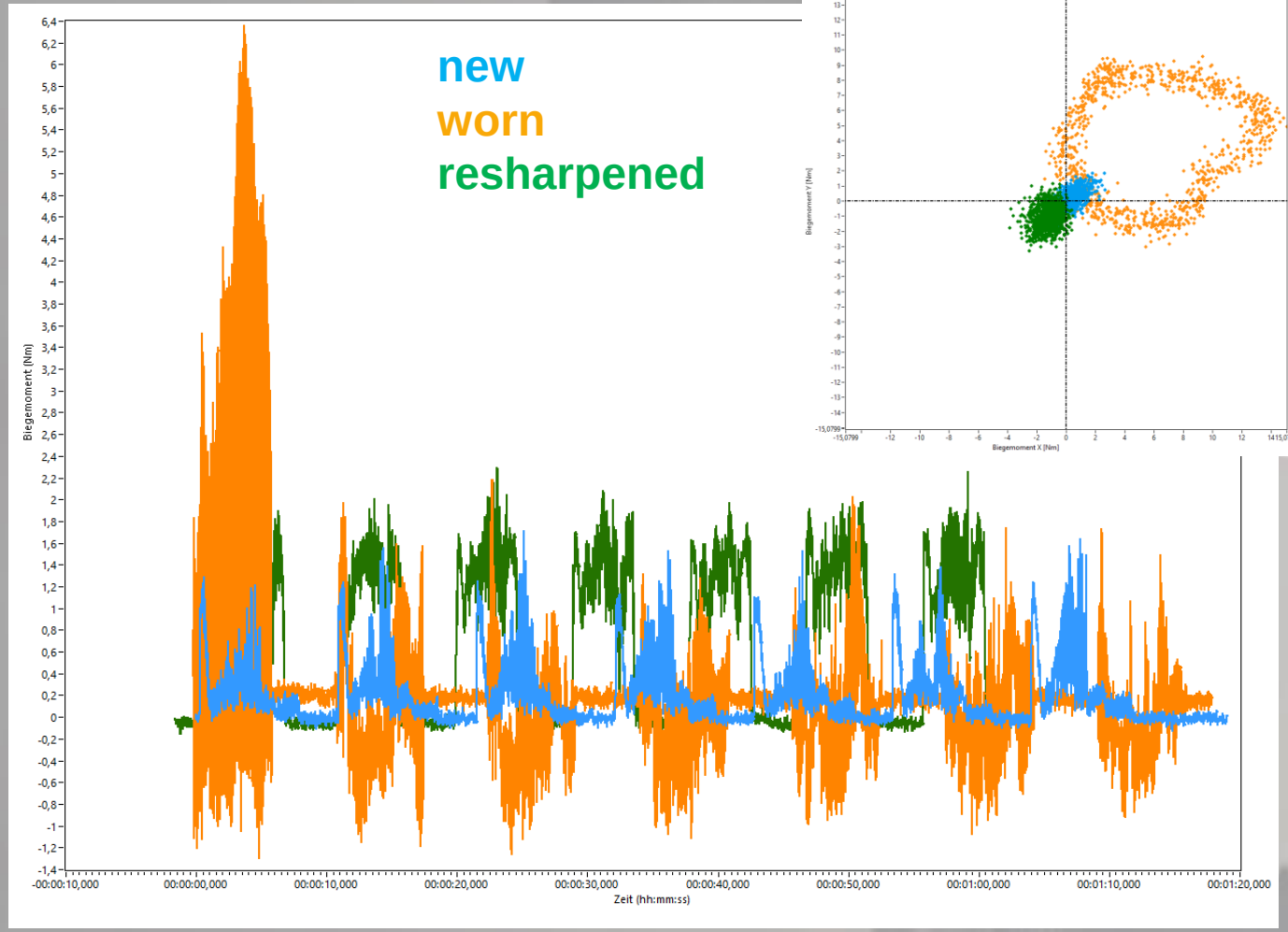


Fig. 2 bending moment

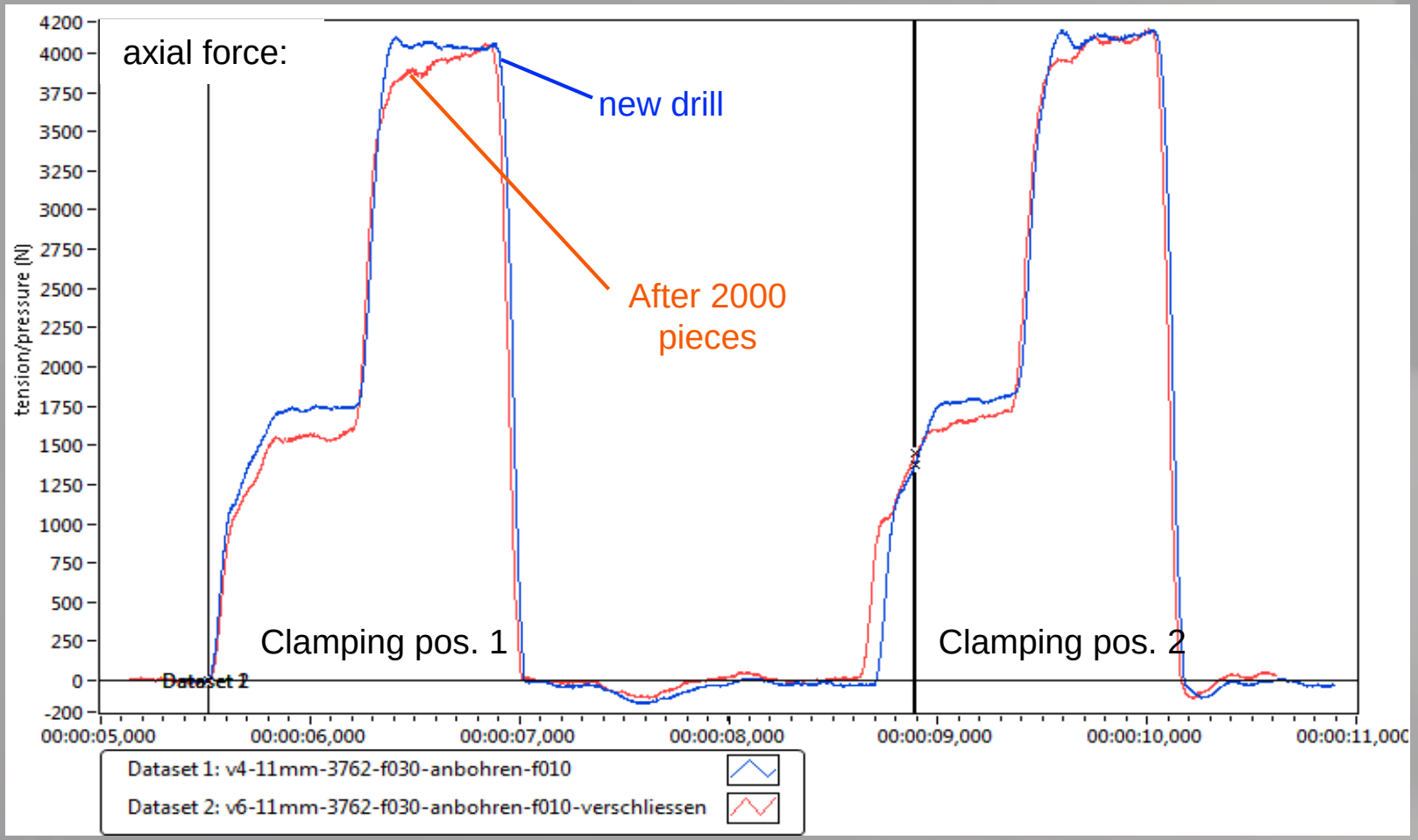


Wear analysis 2

State	Tool	
new		
worn		
resharpened		



Secure maximum tool exploitation - Tool comparison

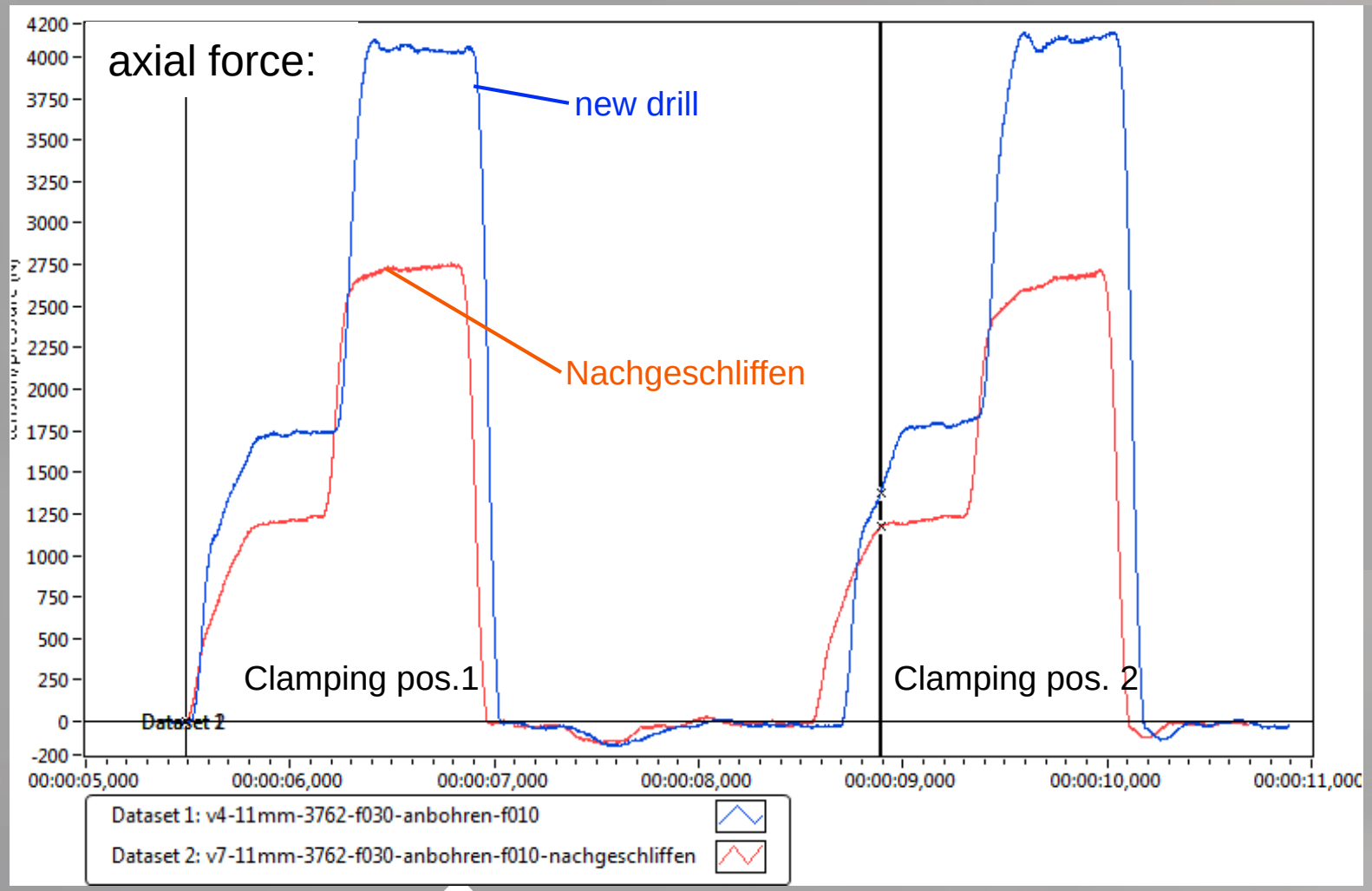


Cutting edge geometry of new drill

Result:

- No increase in axial force discernible
- Drill bits are replaced too early
- Longer tool life possible

Secure maximum tool exploitation - Tool comparison



Result:

- Clearly different characteristics of the cutting forces.
- Reground drill bits differ significantly in geometry from new tools.
- Different tool life!

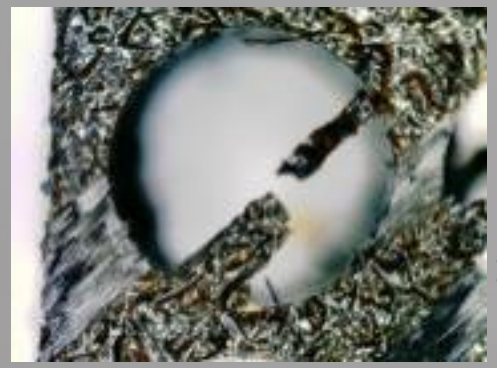
new drill

resharpened

Drill test in CFRP

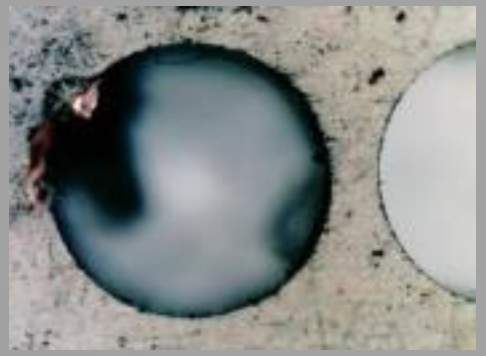
front

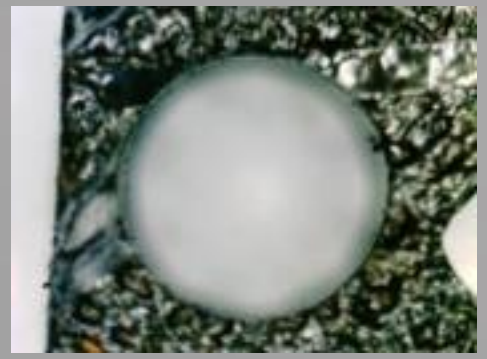
back



Material: CFRP 5mm

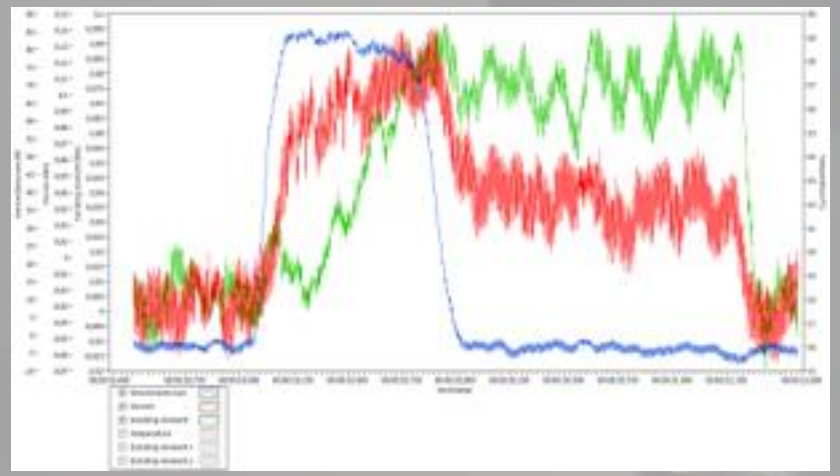
drill 1: blue graph





drill 2: orange graph

Overview of forces: drill 1



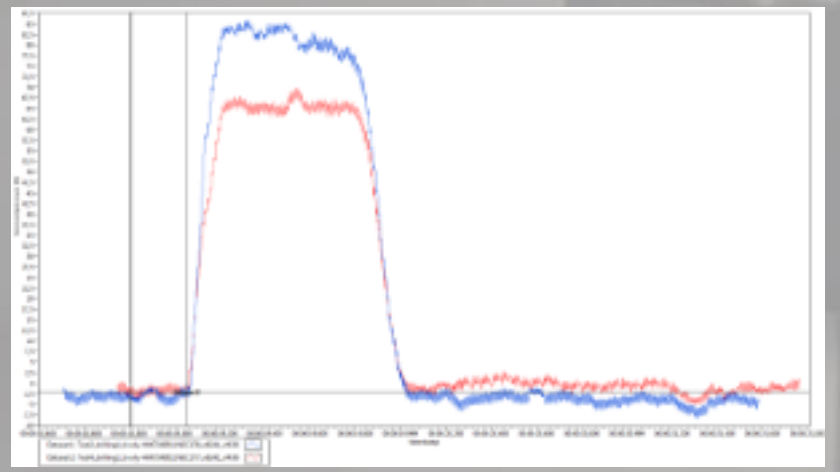
n=436
vf = 305 mm/min

Axial Force

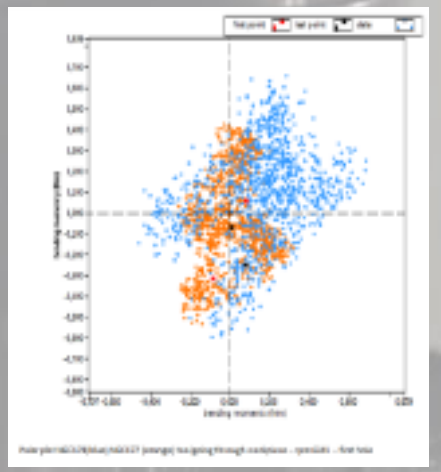
Torsion

Bending Moment

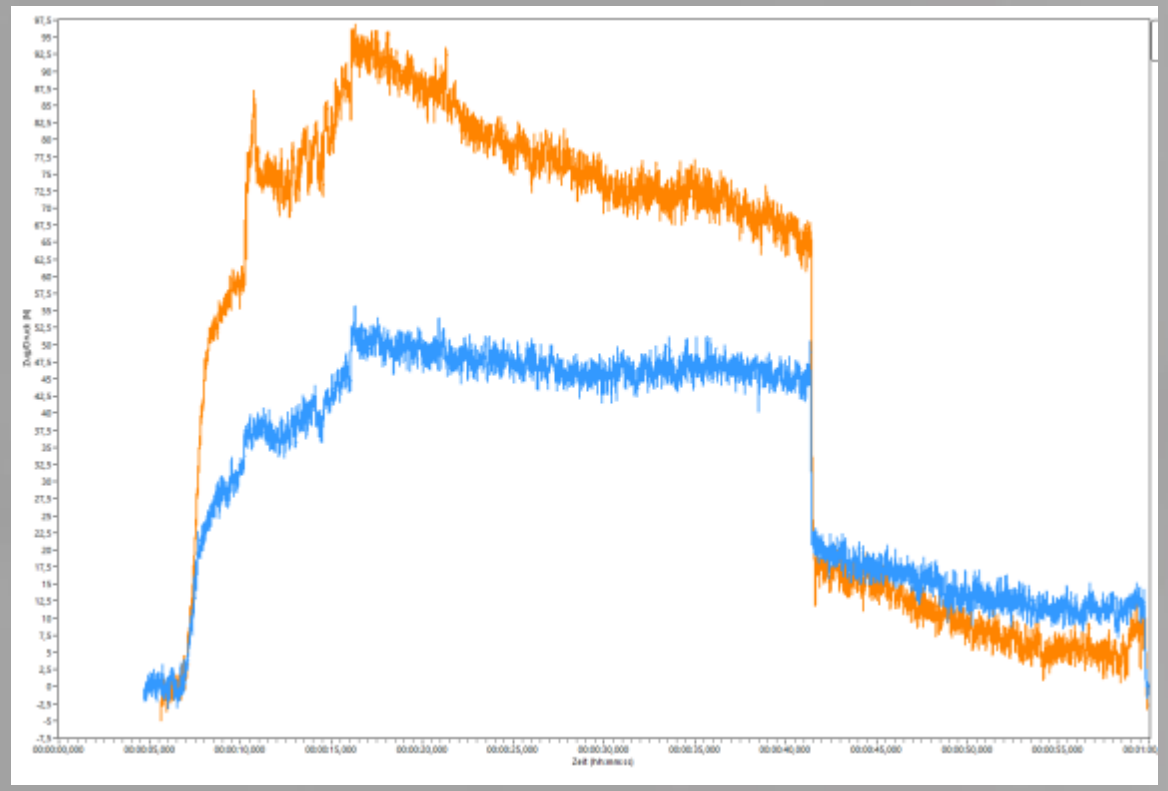
Comparison axial force: drill 1 and 2



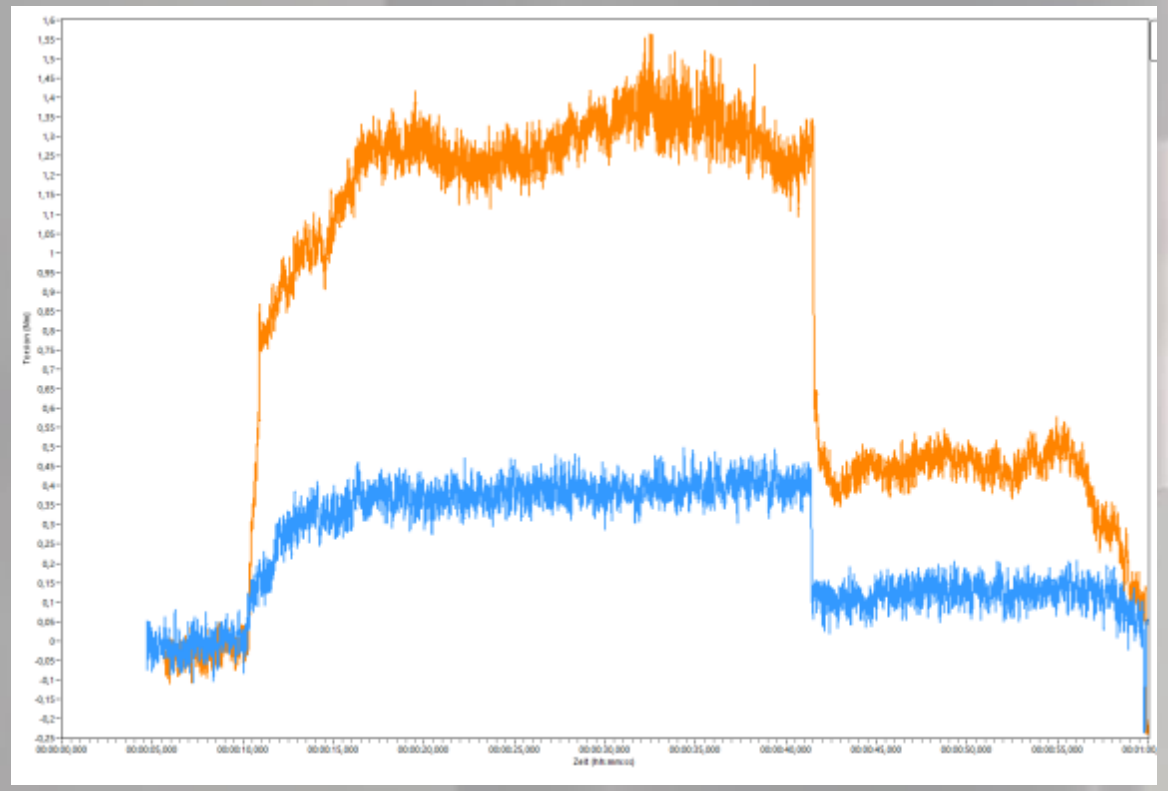
spike_polar



Direct power comparison of the tool condition

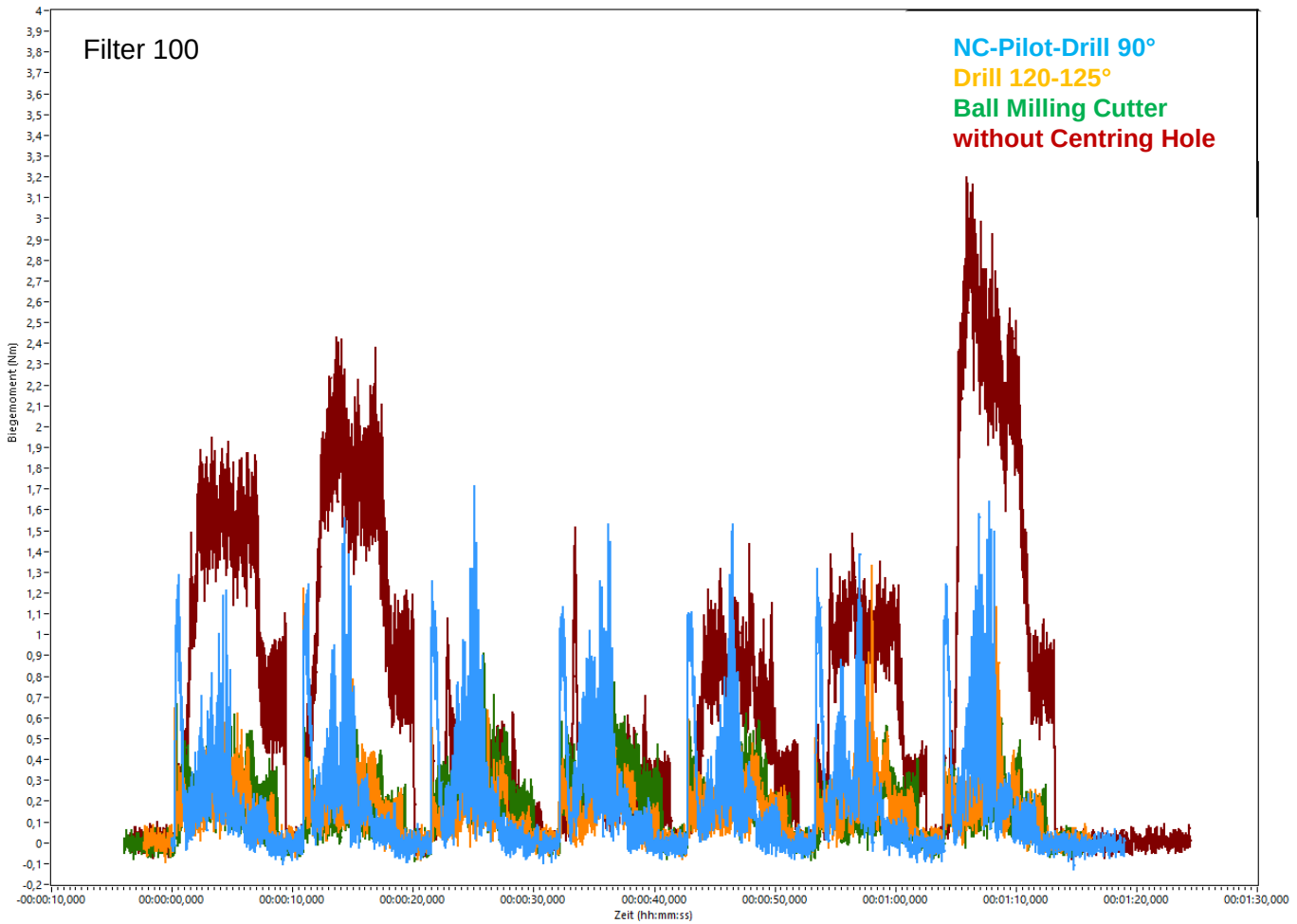


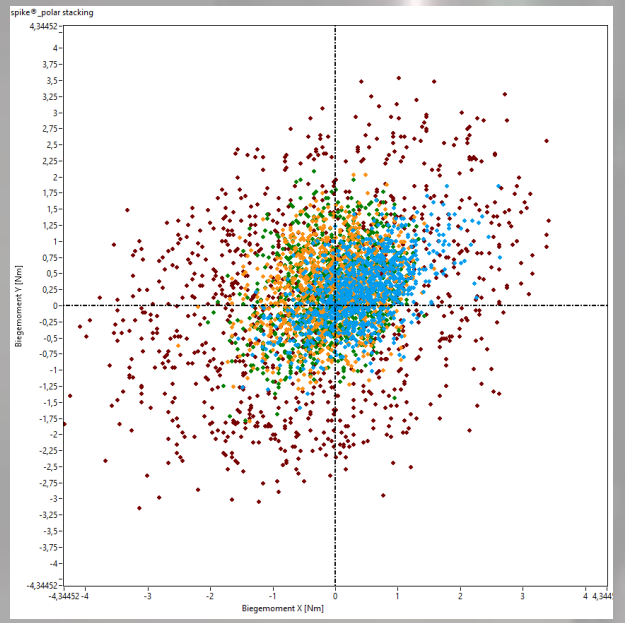
Axial force New / Worn



Torsion moment New / Worn

Comparison of Centring Drilling Holes





Serie 1 – NC-Pilot-Drill 90°

Serie 2 – Drill 120-125°

Serie 3 – Ball Milling Cutter

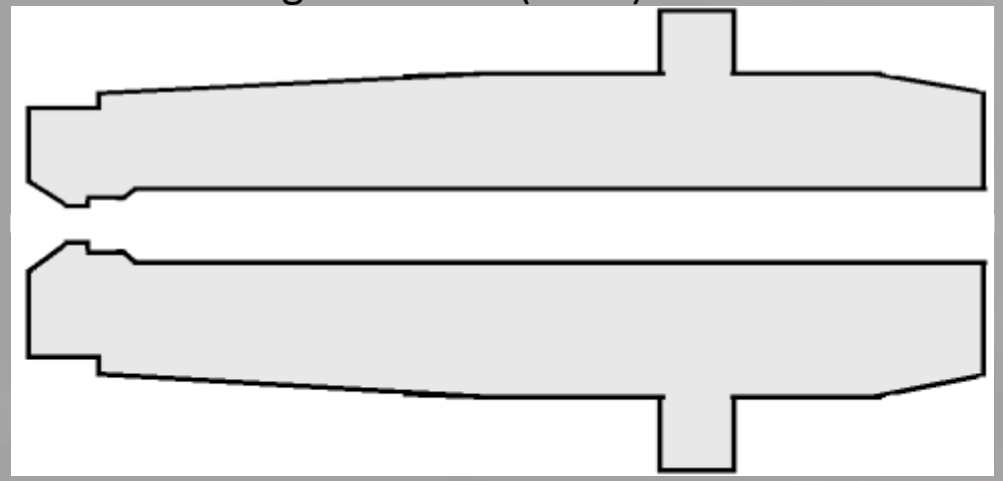
Serie 4 – without Centring Hole

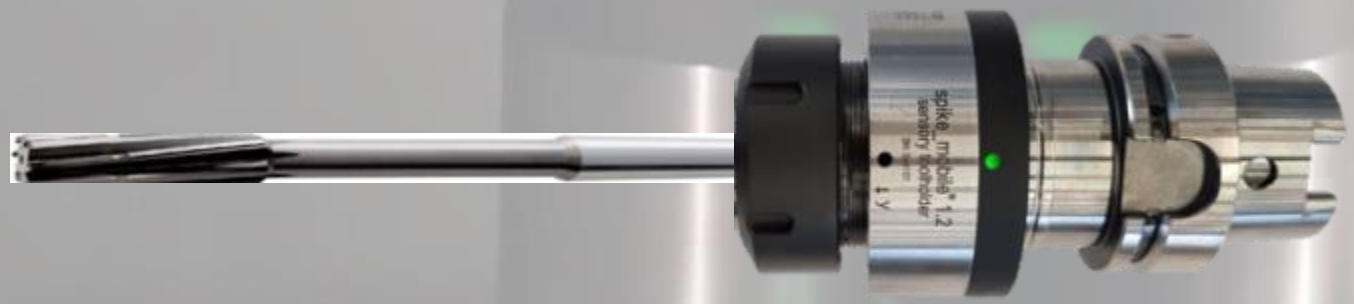
→ Based on the bending moment curve, the process can be optimized and a selection for a suitable pilot drill can be made.

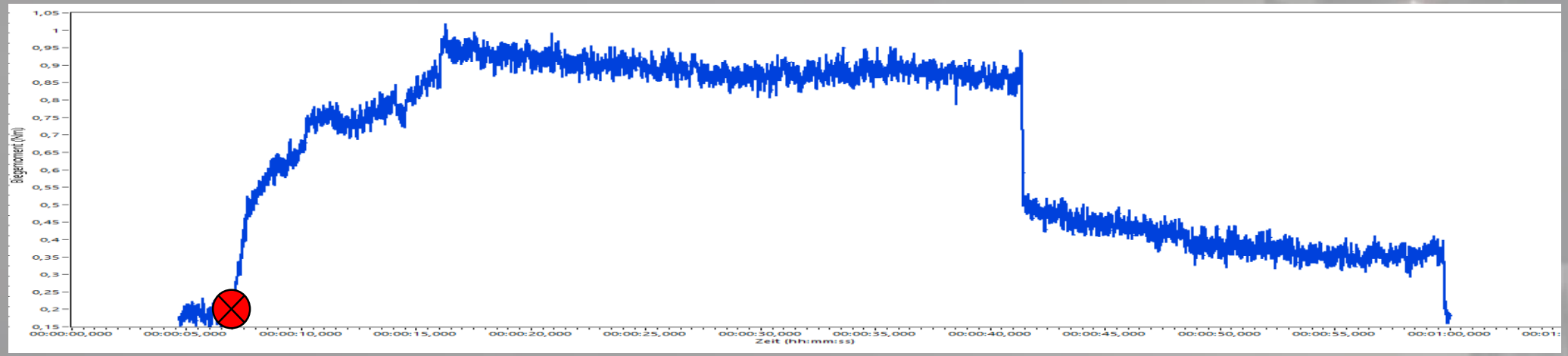
How to identify the low hanging fruits?

1. Process analysis

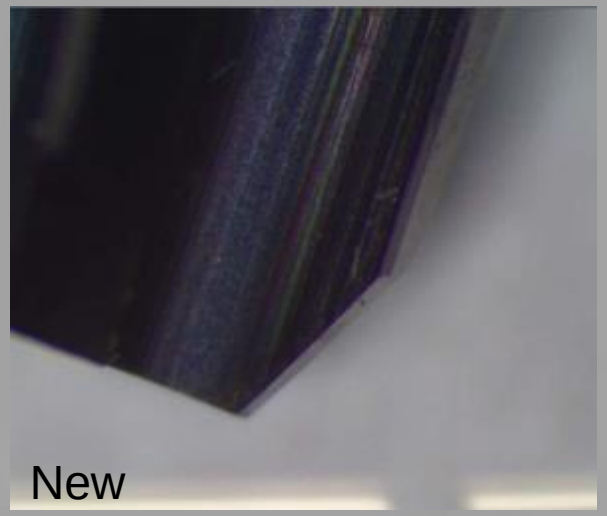
Fit: 7 ^{H7} – length: 77 mm (11xD)

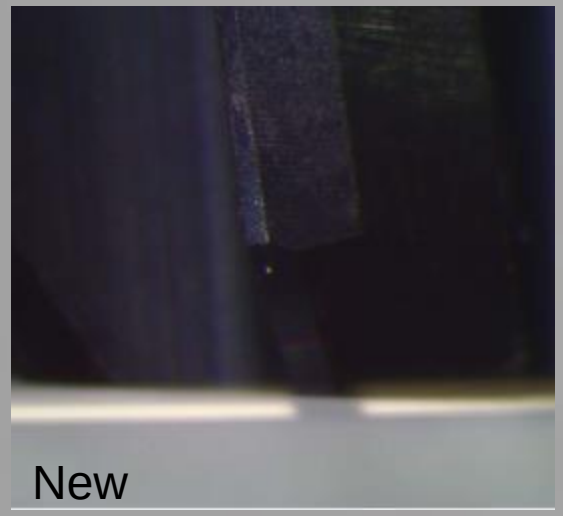




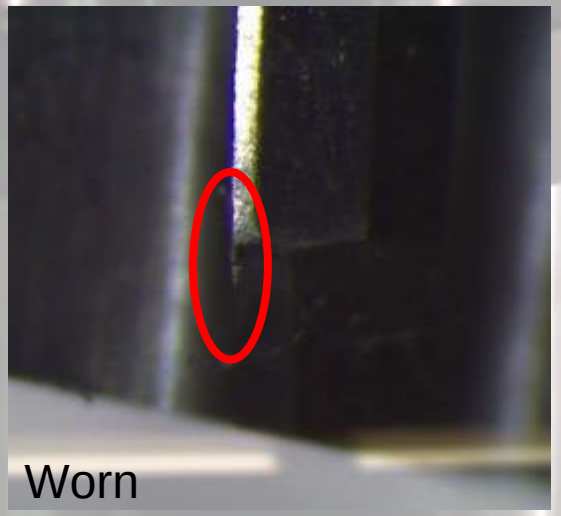


Problem 1 – Wear of the tool

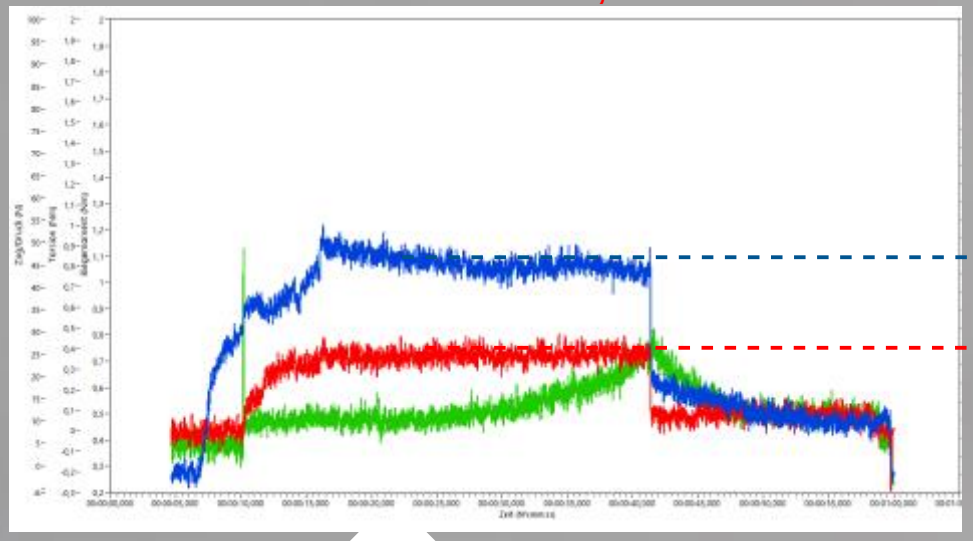

New


New

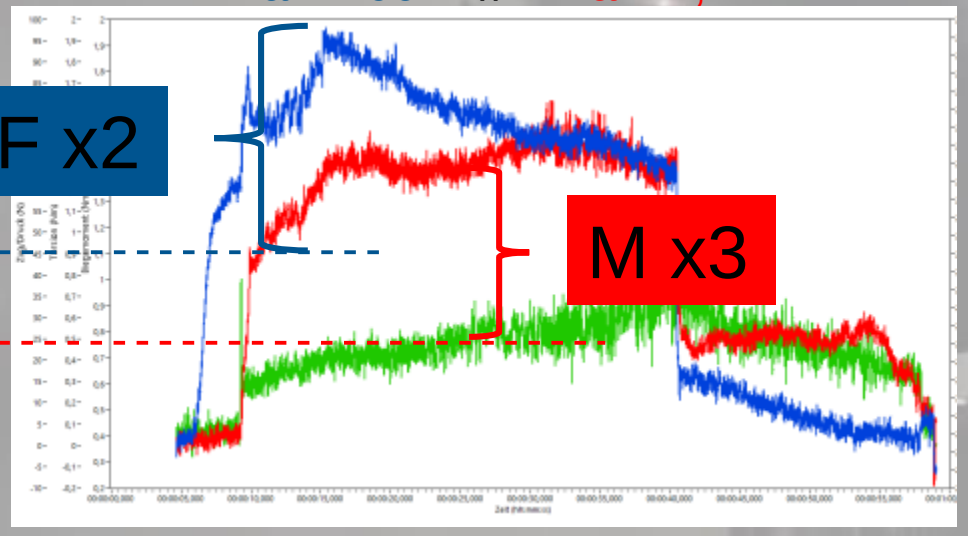

Worn


Worn

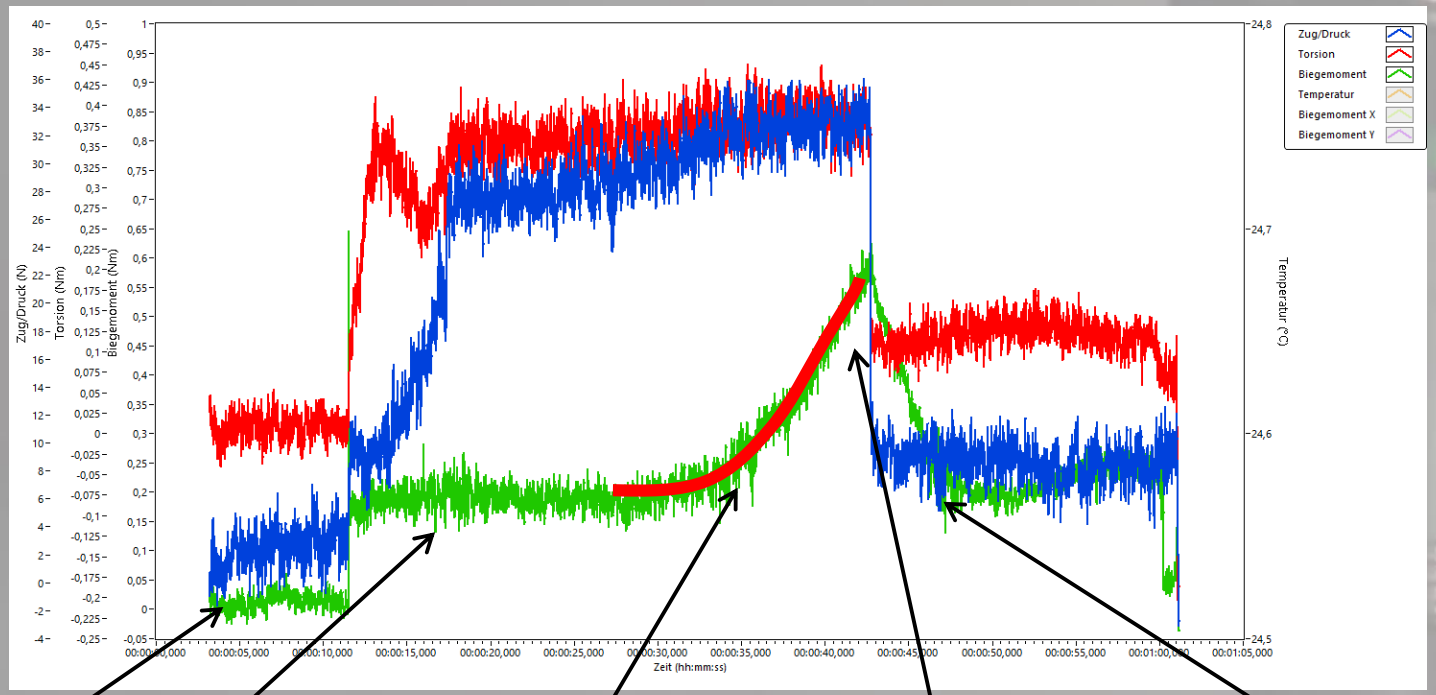
Fmax: 50 N // Tmax: 0,4 Nm



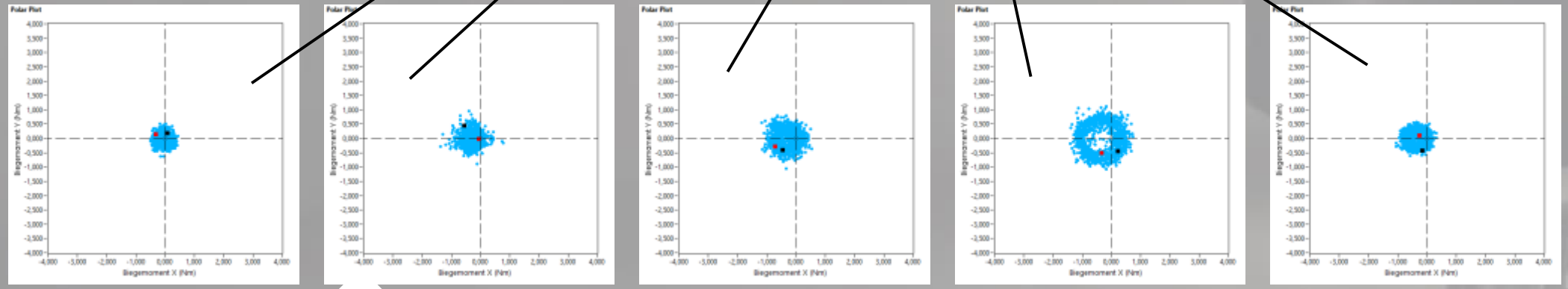
Fmax: 100 N // Tmax: 1,4 Nm



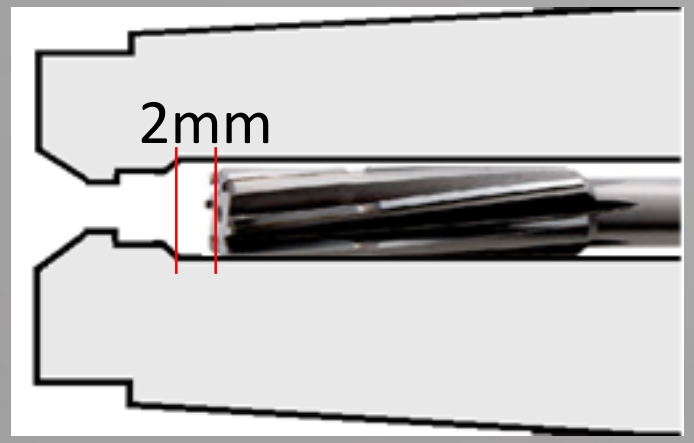
Problem 2: Drill course (recognizable through the bending moment)

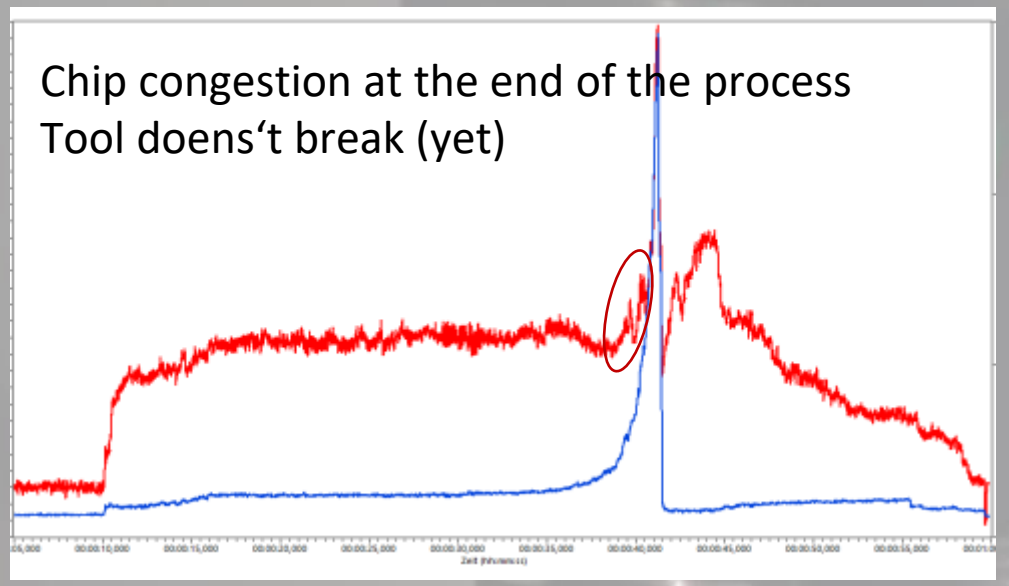


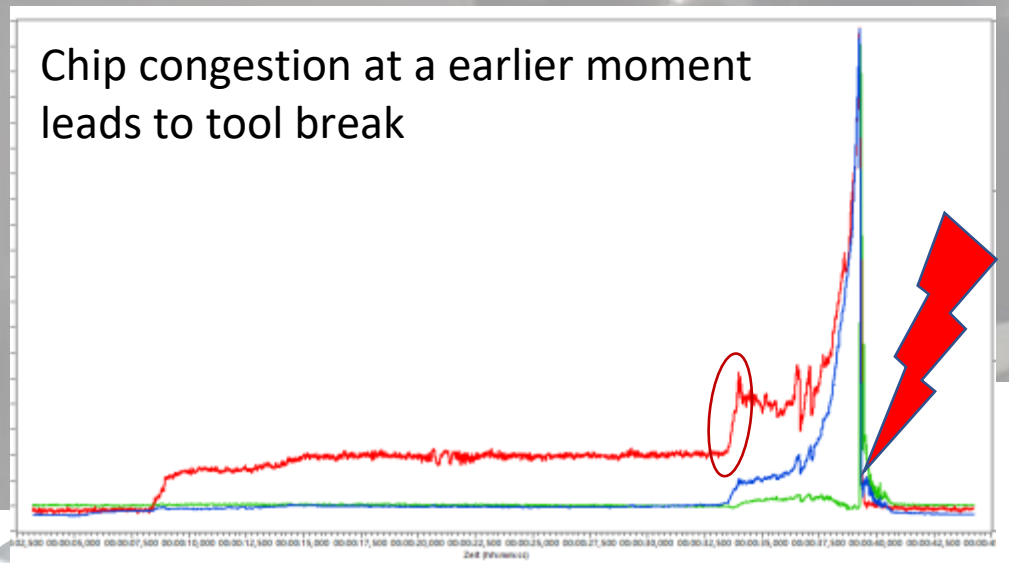
Reamer proceeds with the drill hole
(Cause is the driller)



Problem 3 – not systematized chip congestion







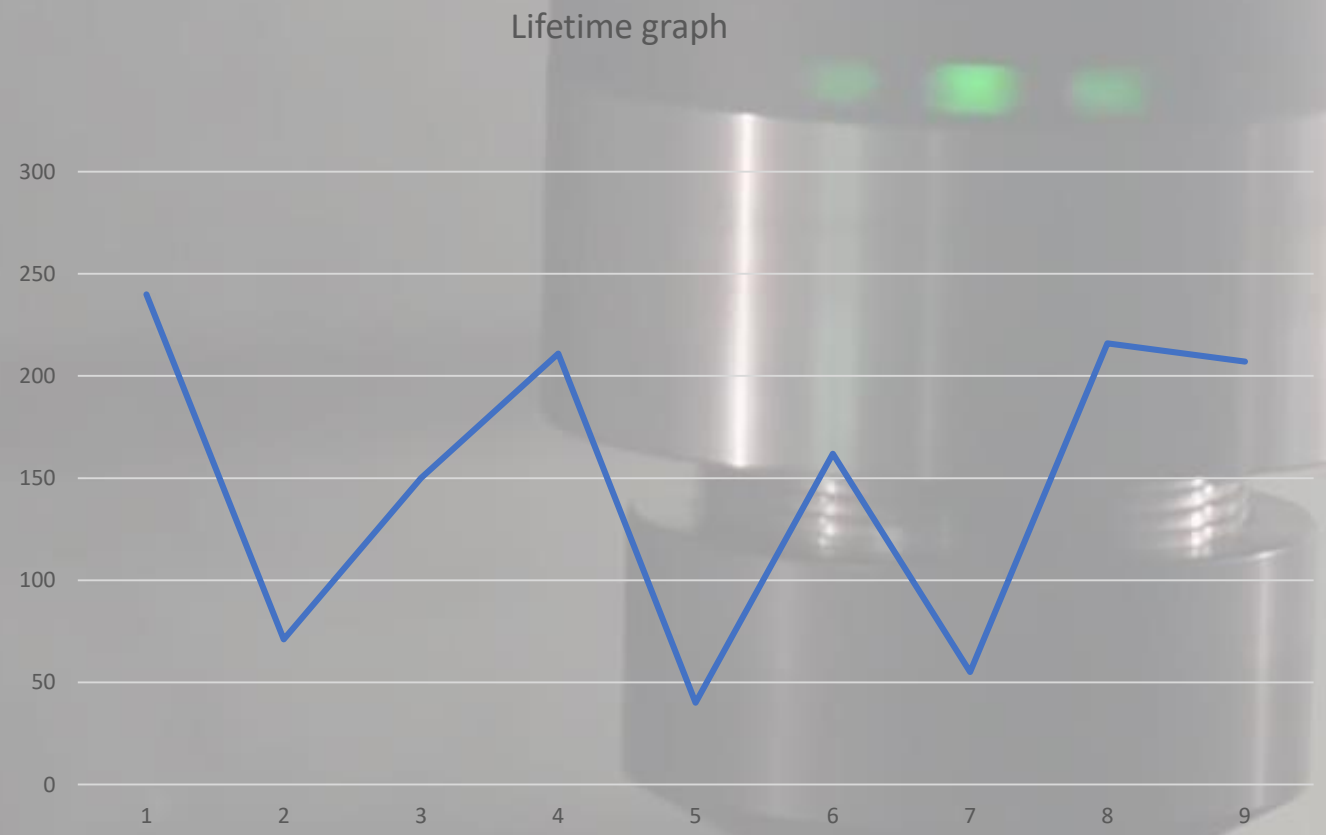
Break of the tool

Tool lifetimes

Overwiew of tool lifetimes (reamer):

1) 240 Minutes
2) 71 Minutes – Break
3) 150 Minutes
4) 211 Minutes
5) 40 Minutes – Break
6) 162 Minutes
7) 55 Minutes – Break
8) 216 Minutes
9) 207 Minutes

(Cycle time appr. 0,8 Min / Component)



Difference of the lifetimes appr. 17,5% in average

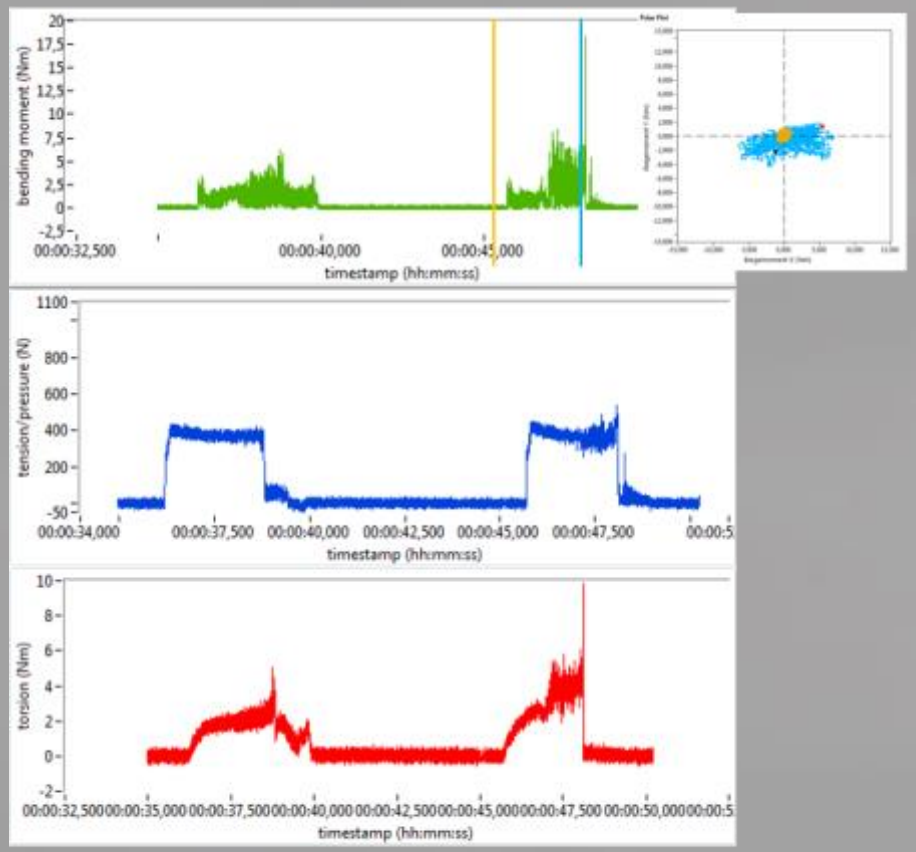
Break after appr. 432 parts in average

Amortization

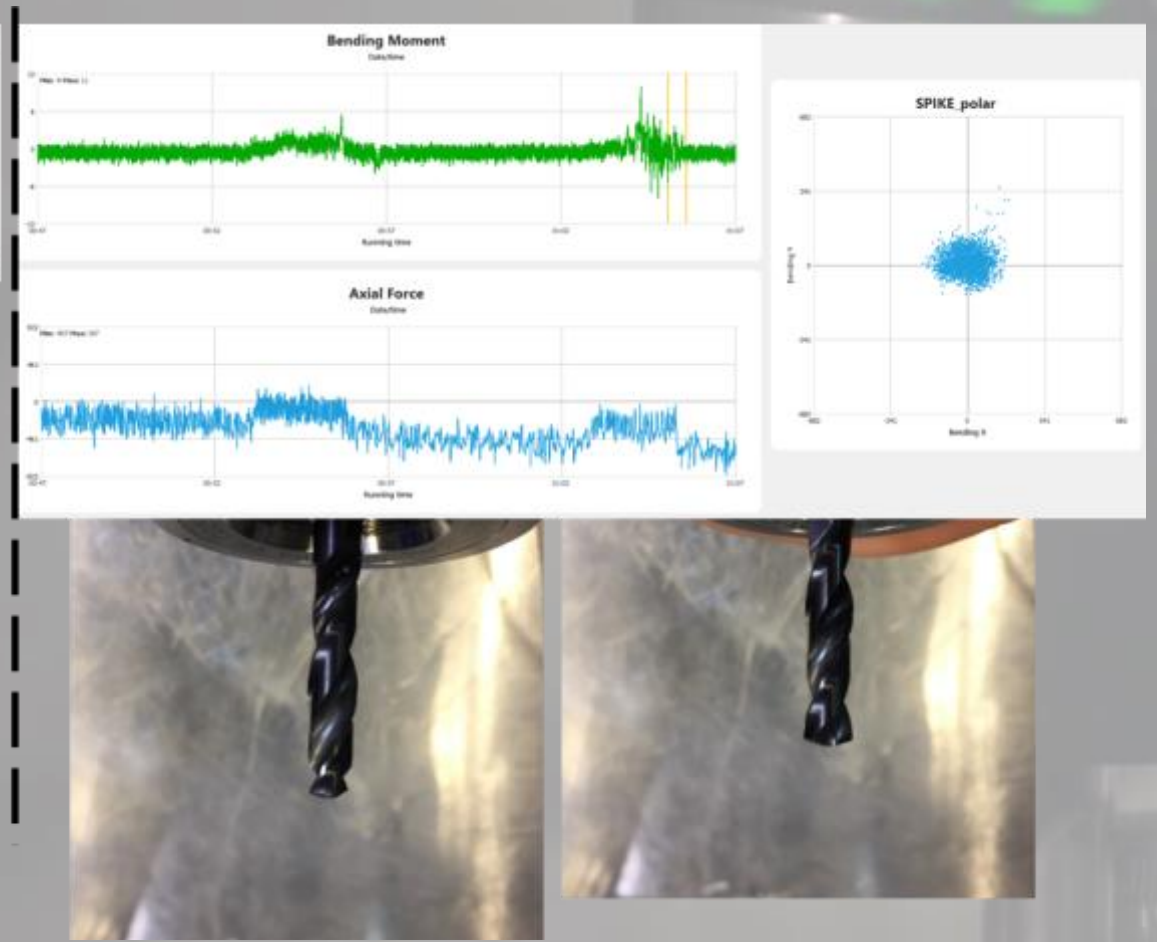
Pieces per hour	12	
Pieces per week	1440	
Pieces per year (less 10% changeover costs)	67.932	
Pieces until break in average	432	
Spoilt rate	1,5%	
Spoilt pieces per year	1010,88	
Costs per component		80,00€
Hourly rate machine	1h	25,00€
Hourly rate staff	1h	30,00€
Downtime after break	0,2h	11,00€
Costs new tool		120,00€
Costs for the regrinding		30,00€
Saving with prevention of break		90,00€
Latest lifetime in pieces	178,5714286	
Needed tolls per year	377,3952	
Tool costs per year		45,287,42€
Optimization of the lifetime	17,5%	
Costs measure machine incl. MA	1h	60,00€
100% control per piece	0,025h	1,50€

Drill Ø5,4mm in TiAl6V4 increased parameter - break

spike_mobile (Category A)

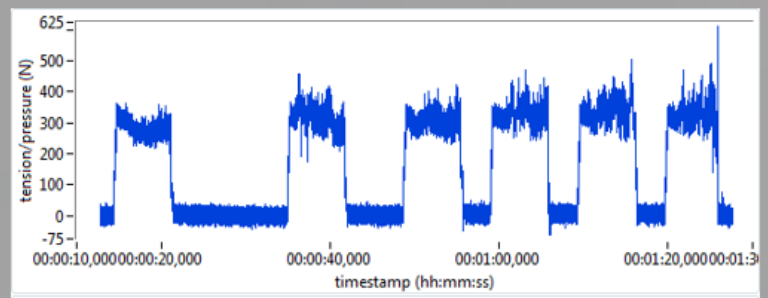


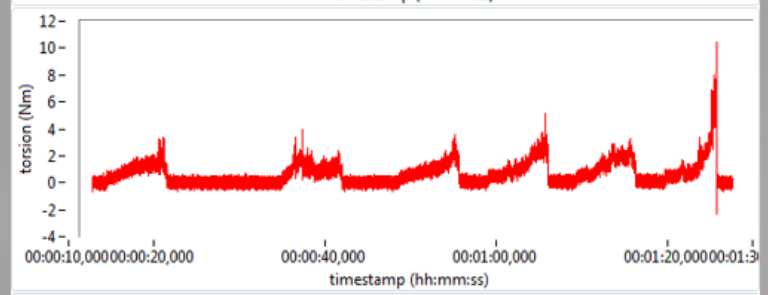
spike_inspindle

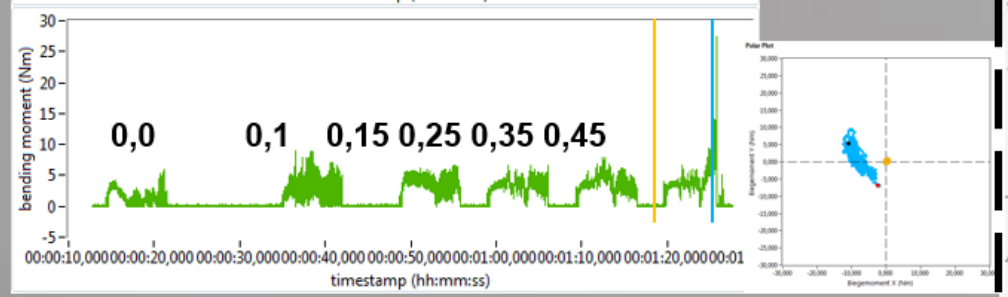


Corehole drill Ø5,1mm in TiAl6V4 with offset

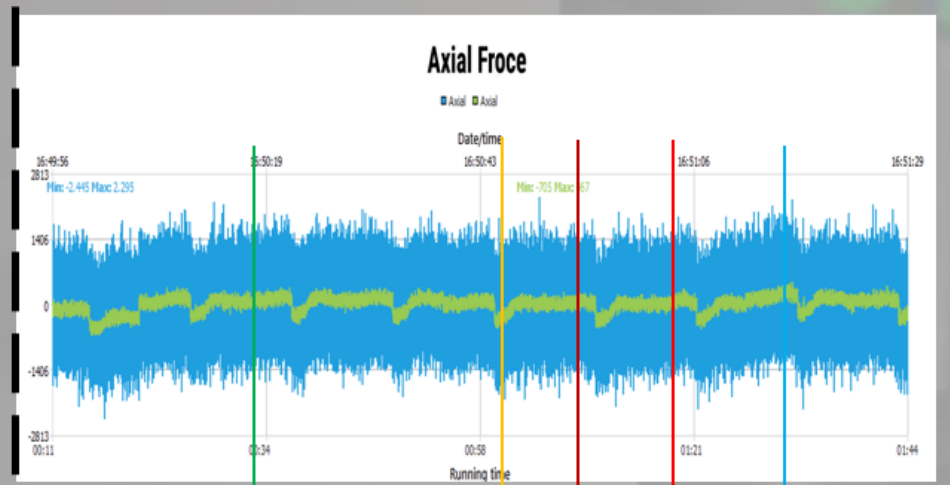
spike_mobile (Category A)

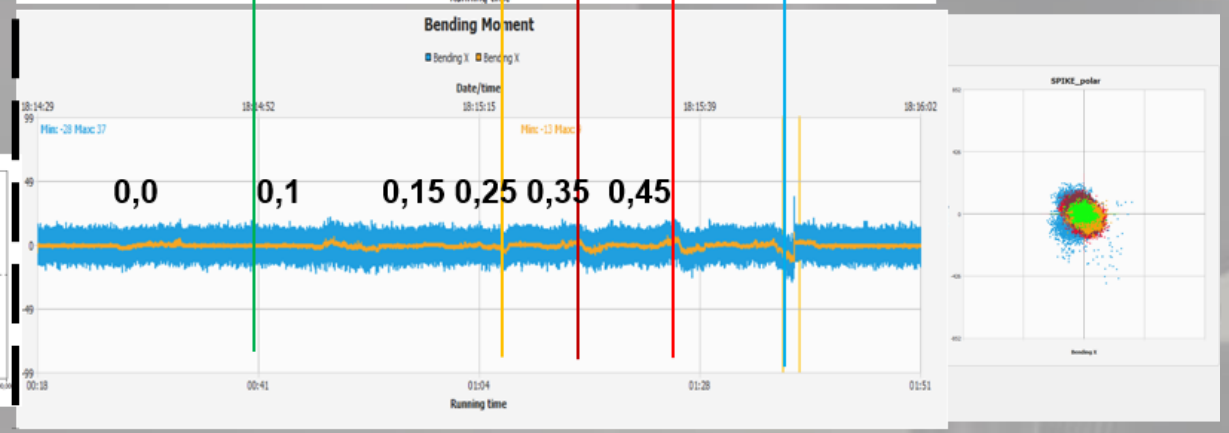






spike_inspindle

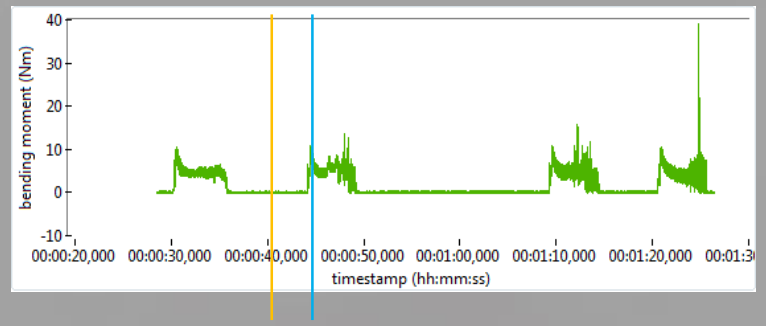


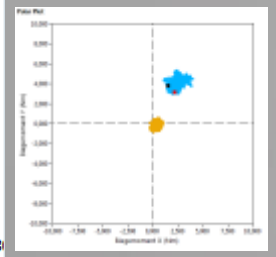


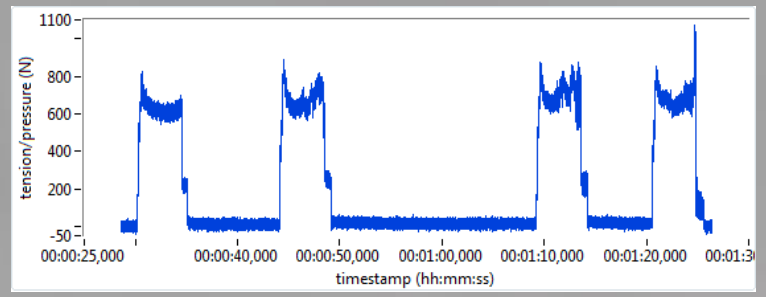
Bending moment:
Filter 100: -13/9Nm
Filter 1: -28/37Nm
Axial:
Filter 100: -1050(?)/518N
Filter 1: -2900/2460N

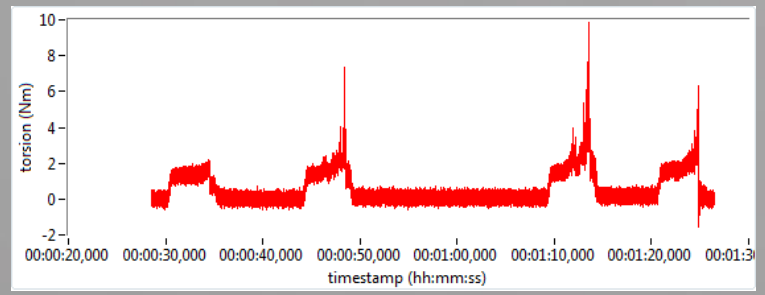
Drill Ø5,4mm in TiAl6V4 one-sided wear

spike_mobile (Kategorie A)

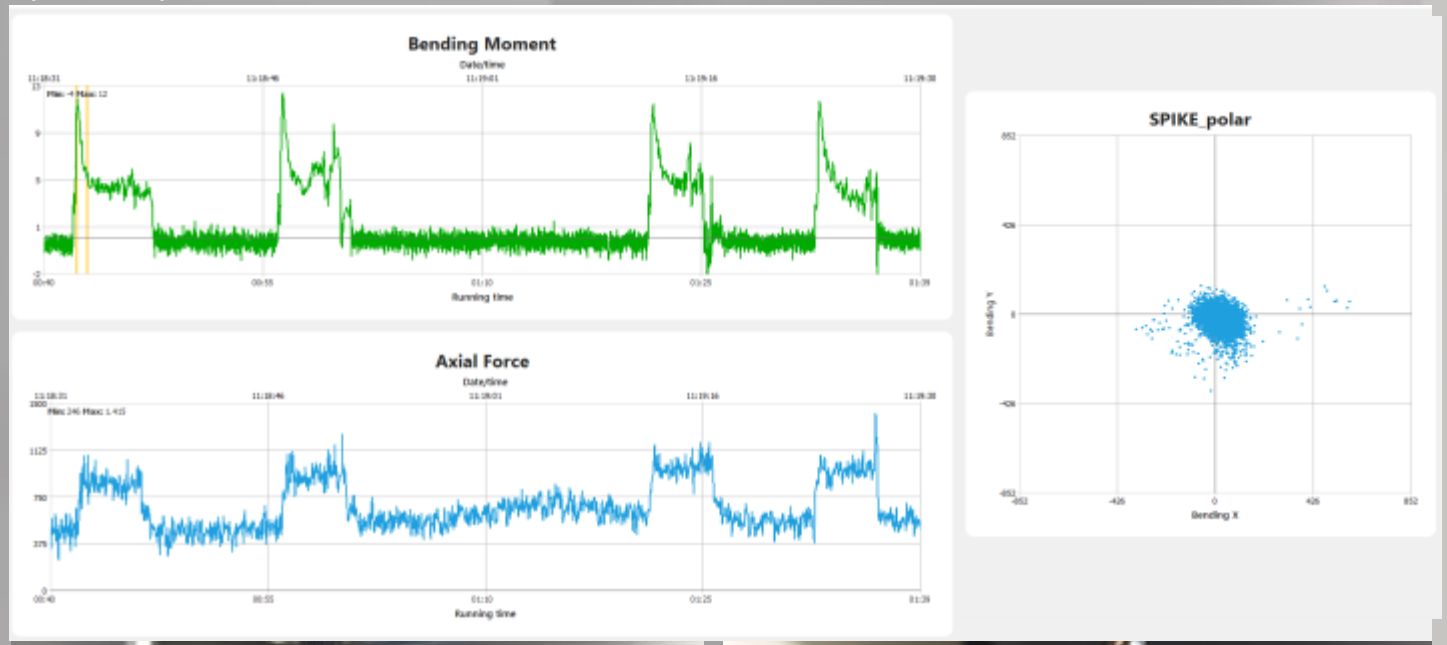








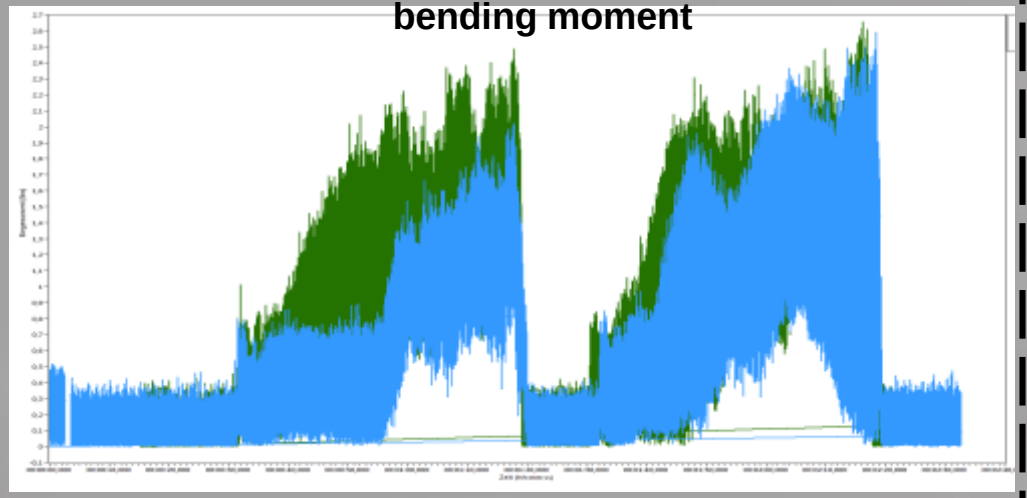
spike_inspindle



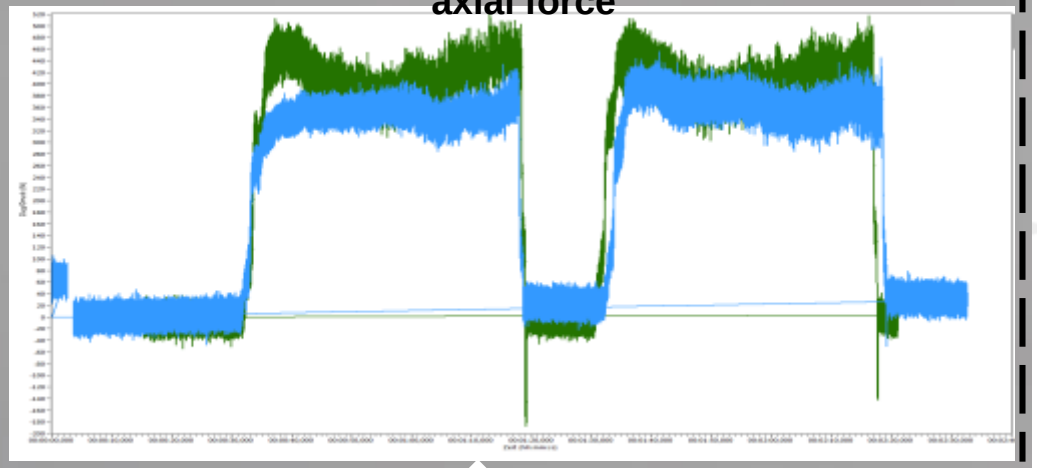
Corehole drill Ø5,1mm HSS in TiAl6V4 wear

spike_mobile (Category A)

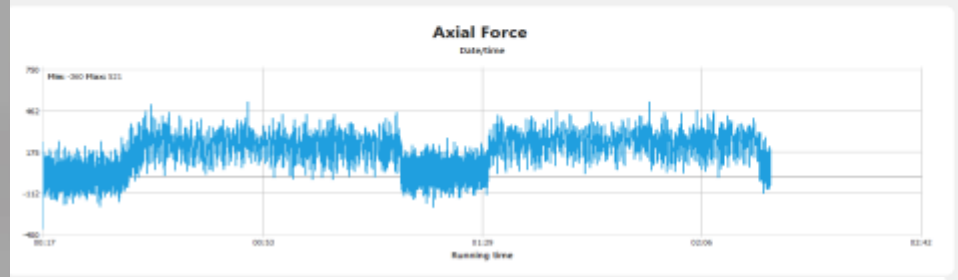
bending moment

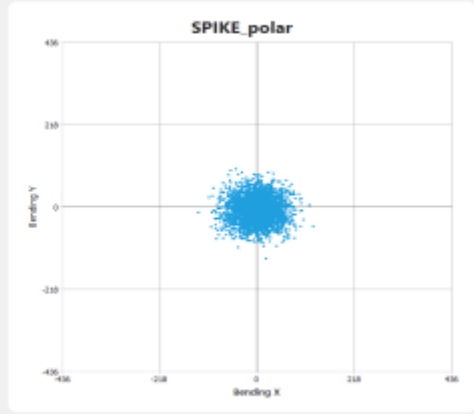


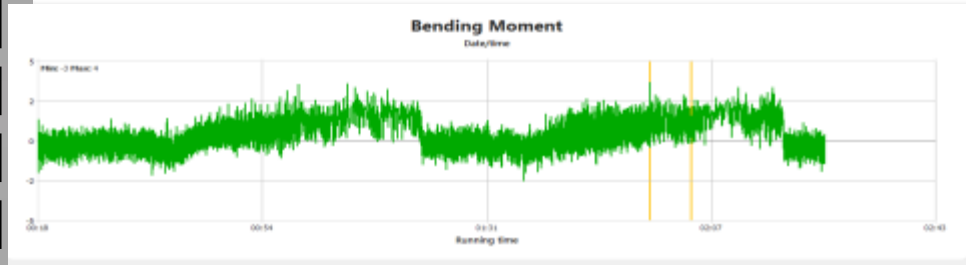
axial force

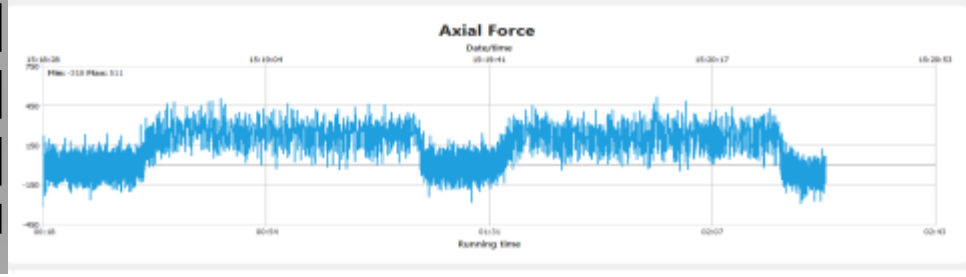


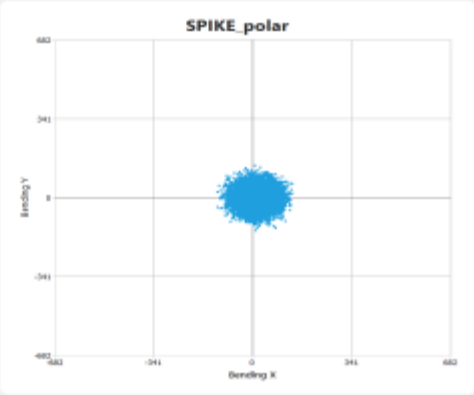
spike_inspindle

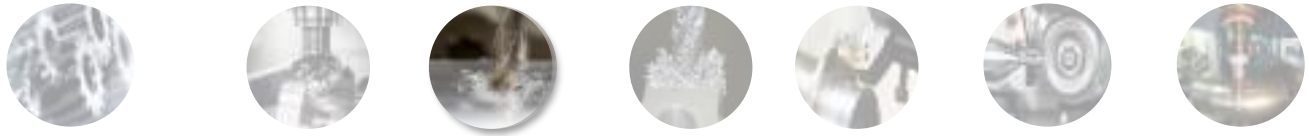






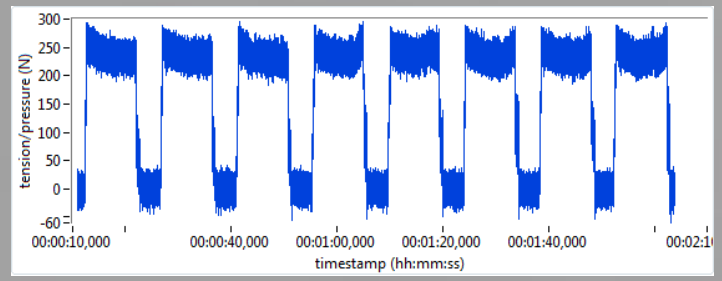


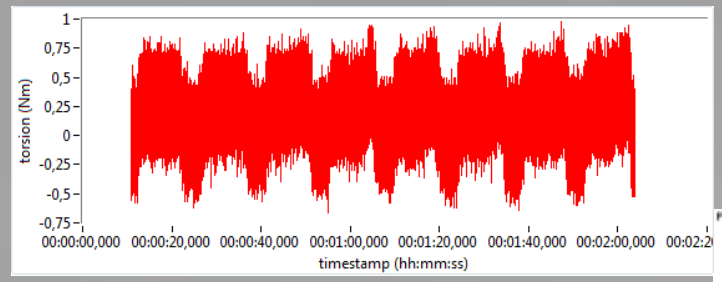


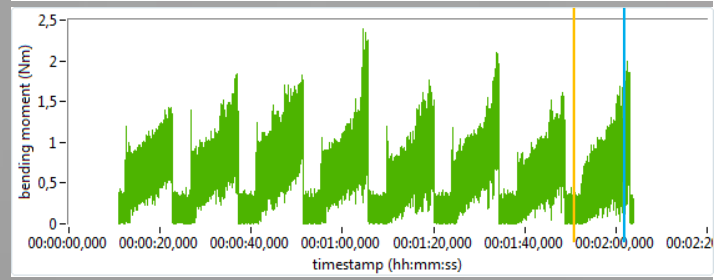


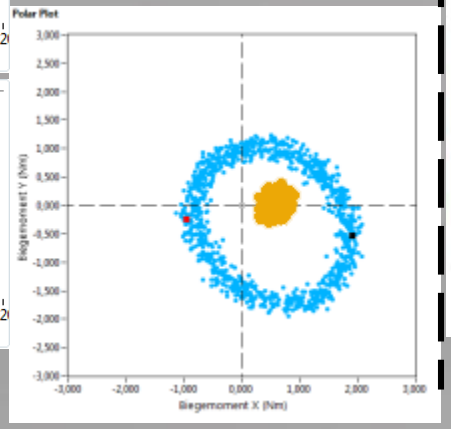
Corehole drill with Ø3.4mm in TiAl6V4 without offset

spike_mobile (Category A)

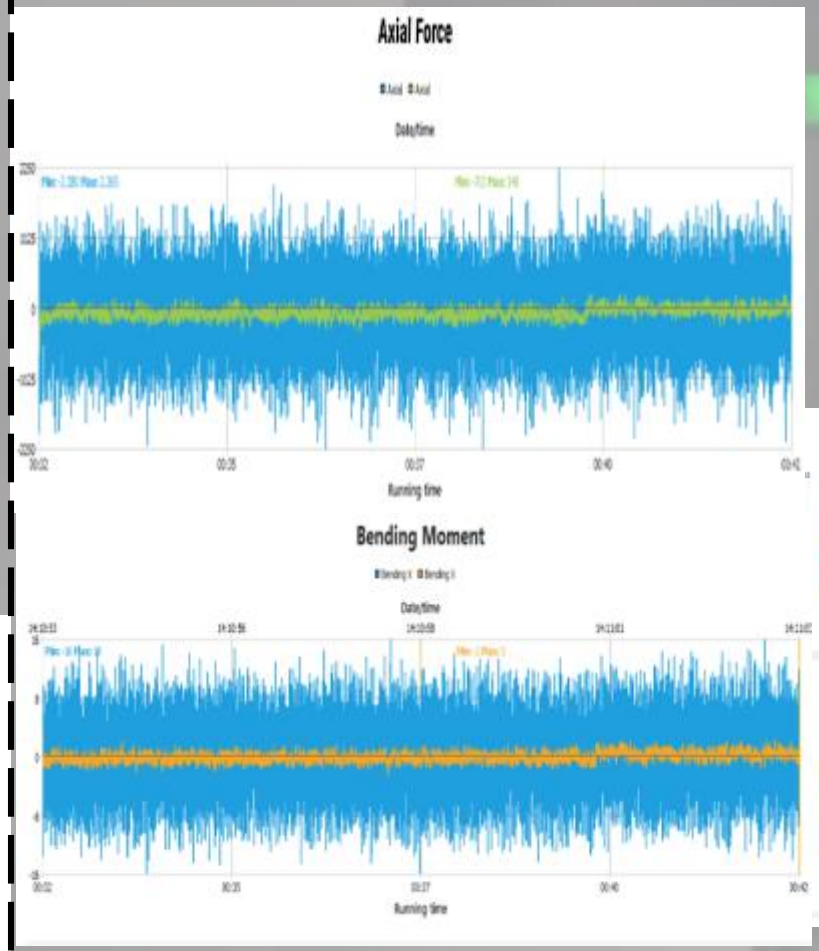




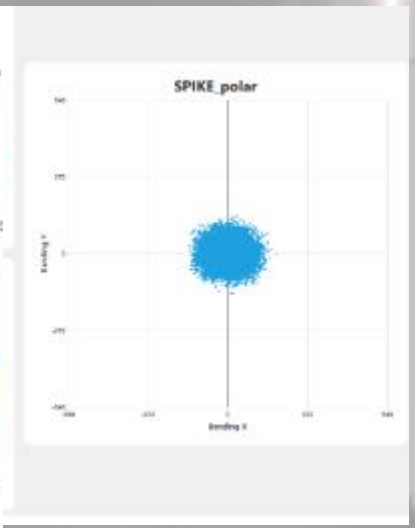




spike_inspindle



Bending moment:
Filter 100: -2/3Nm
Filter 1: -16/18Nm
Axial:
Filter 100: -700/350N
Filter 1: -2280/2265N

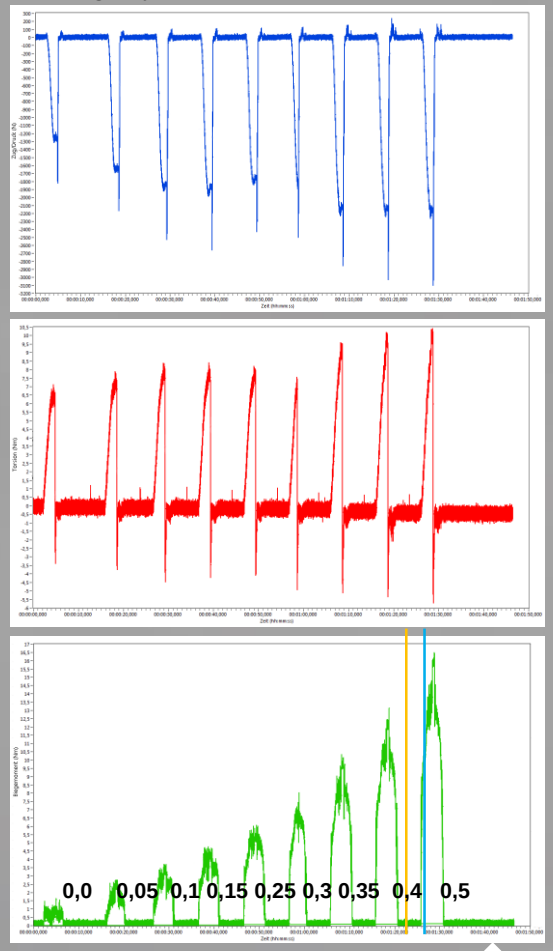


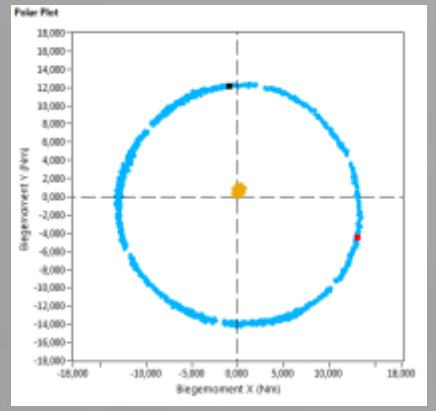
spike® Comparison thread hole M6 in TiAl6V4 with offset

promicron wireless solutions

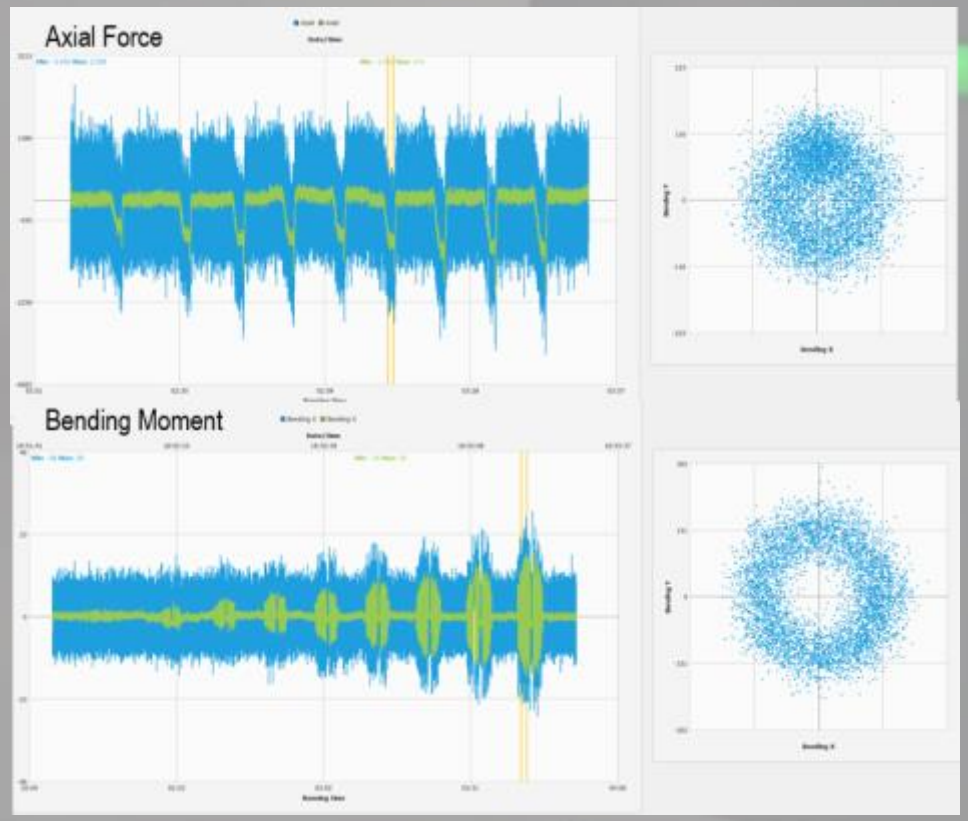
spike®_mobile

Category A





spike®_inspindle



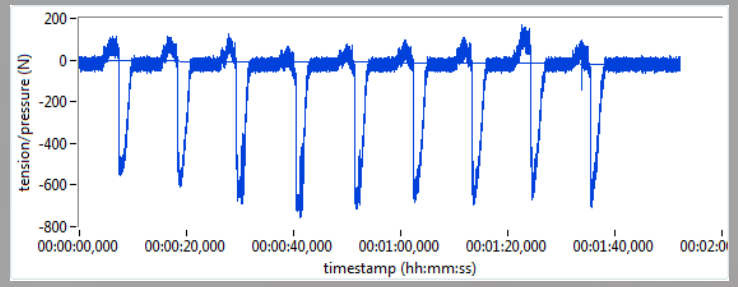
Axial:
Filter 100: -200/414N
Filter 1: -3420/2550N
Bending moment:
Filter 100: -18/20Nm
Filter 1: -28/30Nm

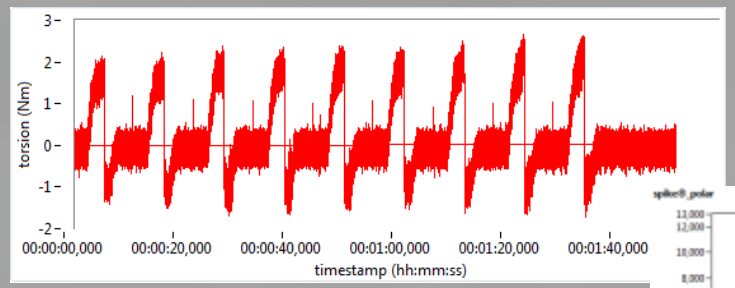
spike® Thread hole M4 in TiAl6V4 with offset

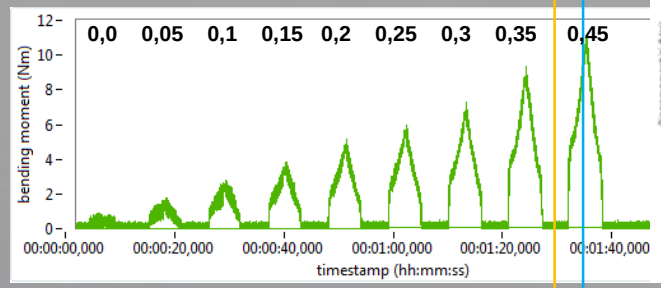
promicron wireless solutions

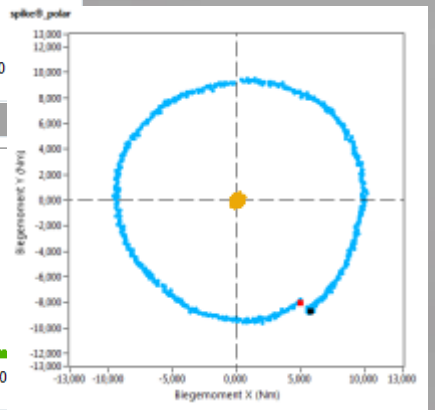
spike®_mobile

Category A

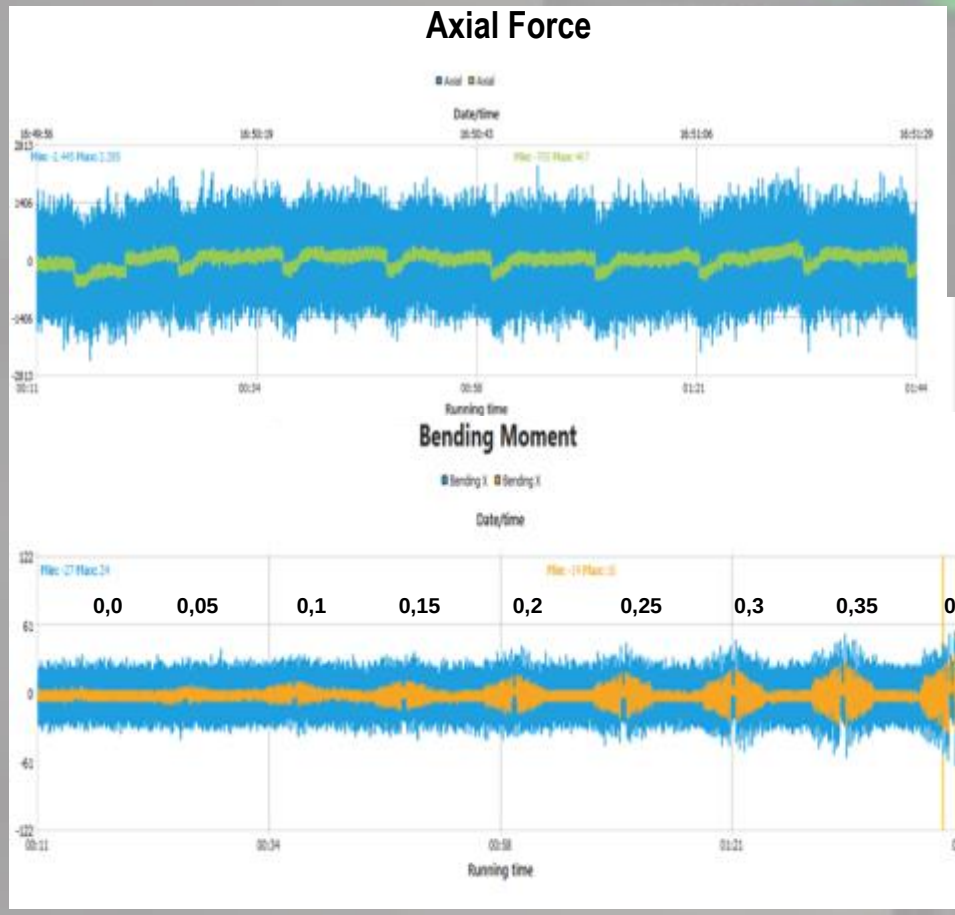




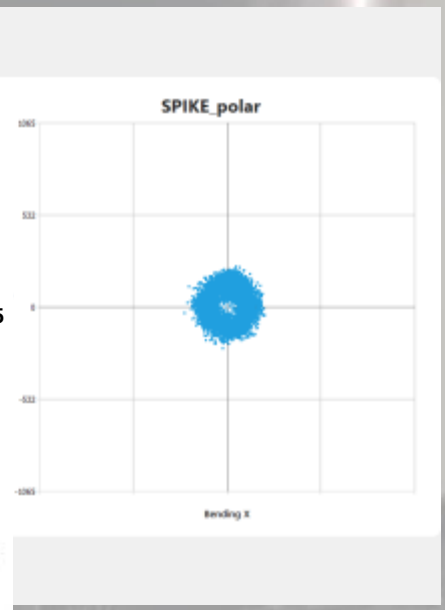


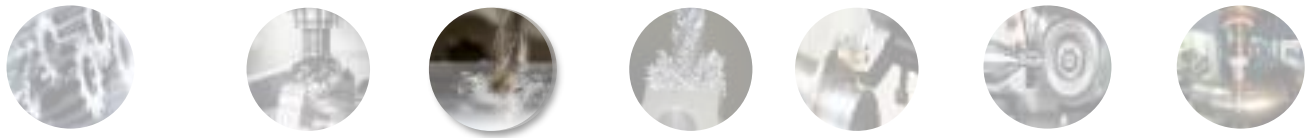


spike®_inspindle



Bending moment:
Filter 100: -14/16Nm
Filter 1: -27/24Nm
Axial:
Filter 100: -700/460N
Filter 1: -2450/2300N



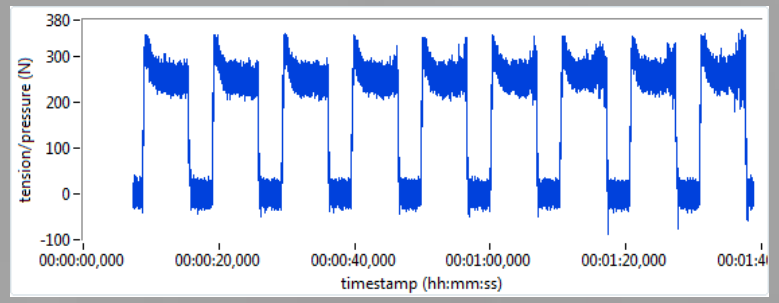


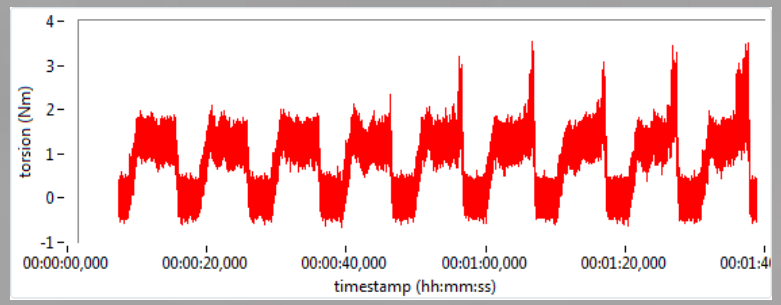
spike® Core hole Ø5,1mm in TiAl6V4 without offset

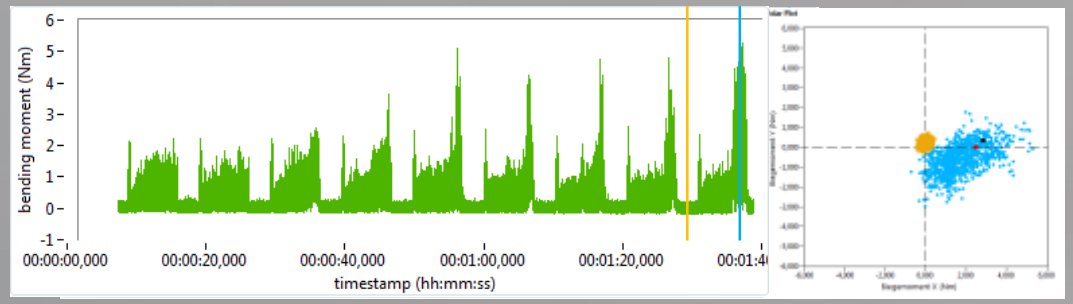
promicron wireless solutions

spike®_mobile

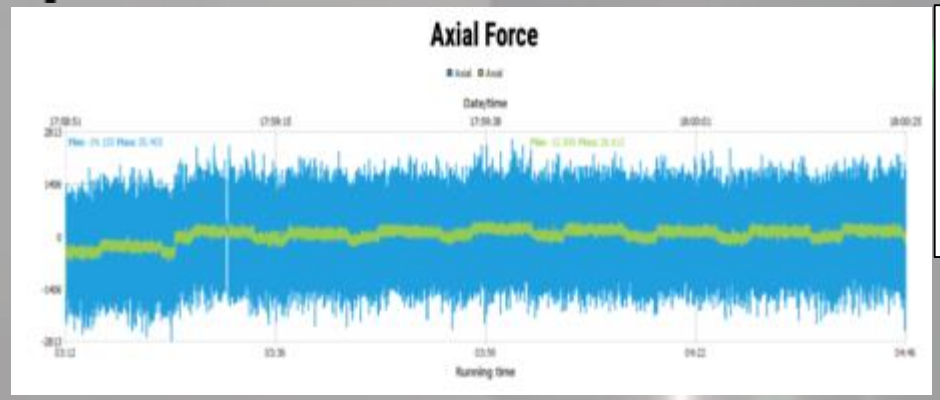
Category A



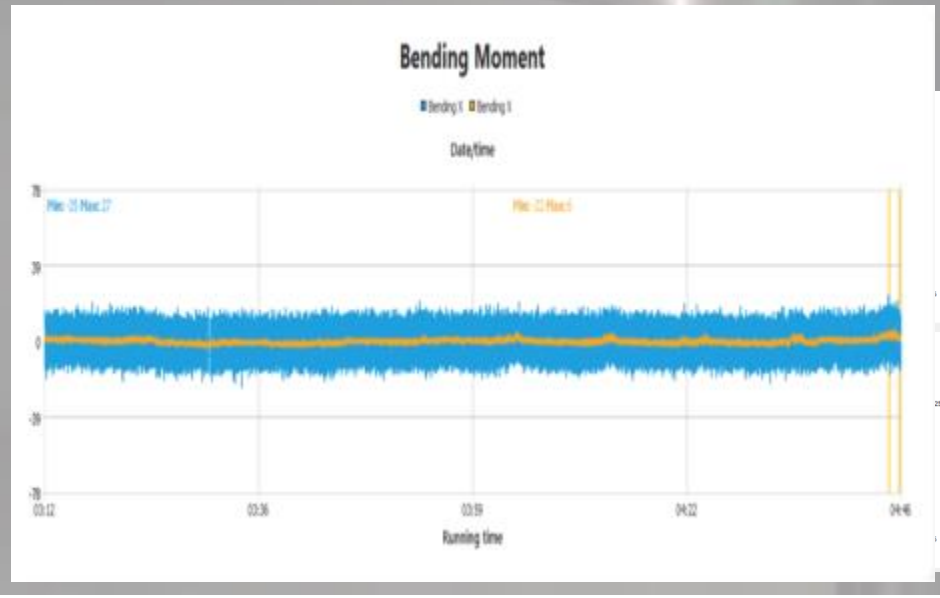


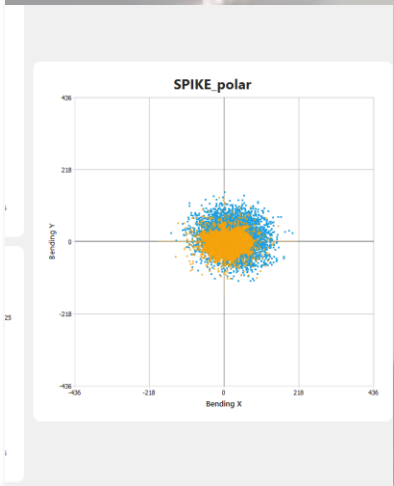


spike®_inspindle

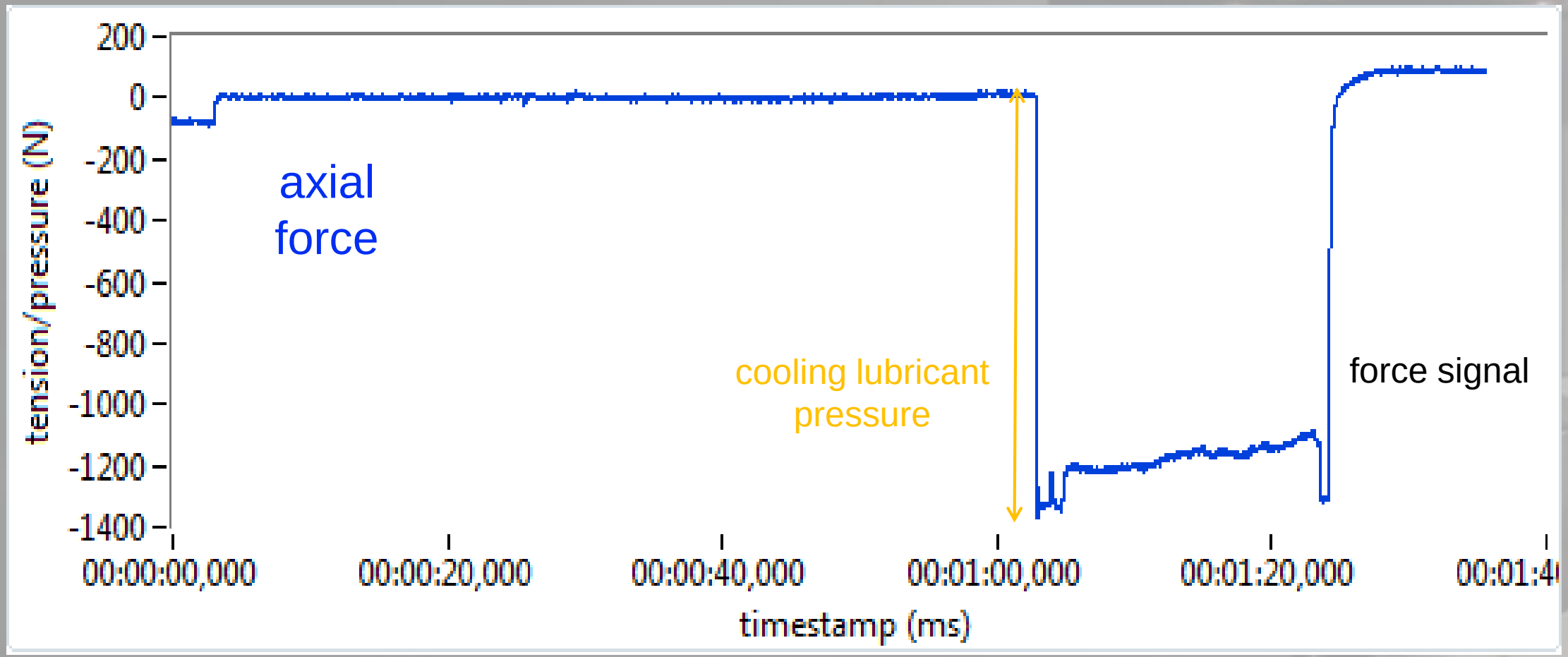


Bending moment:
Filter 100: -22/6Nm
Filter 1: -35/27Nm
Axial:
Filter 100: -XXX
Filter 1: -2800/2560N





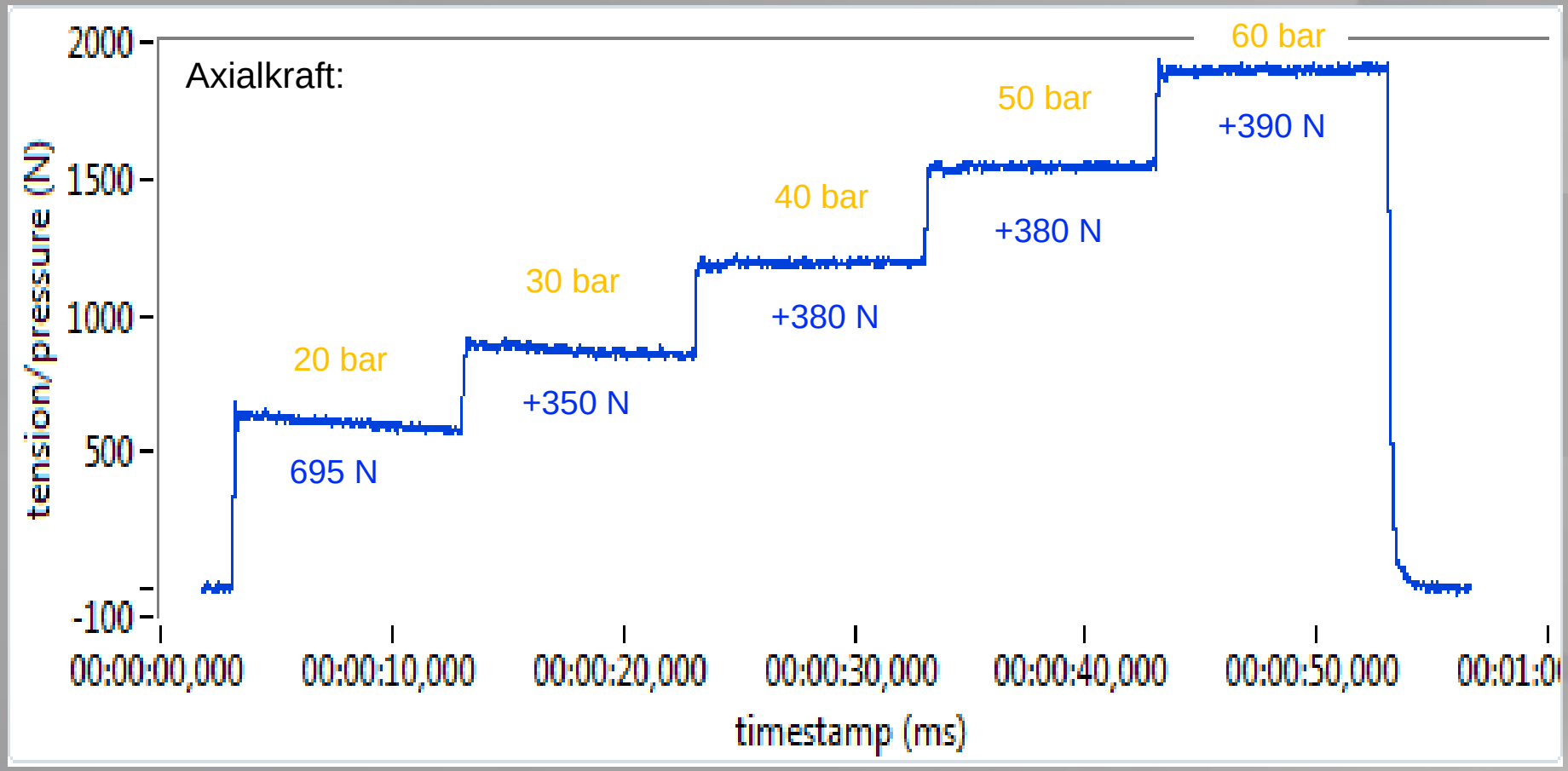
Deep hole drilling



Process analysis / machine monitoring:

Pressure changes at the tool holder are measurable with inner cooling through axial force

Variation inner cooling pressure

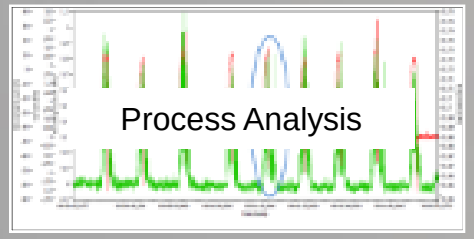


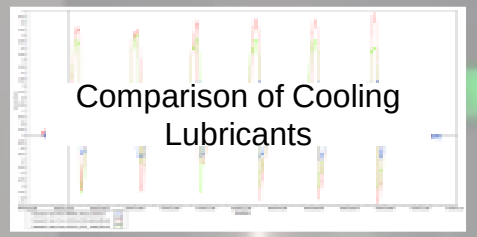
Process Analysis / Machine Monitoring:

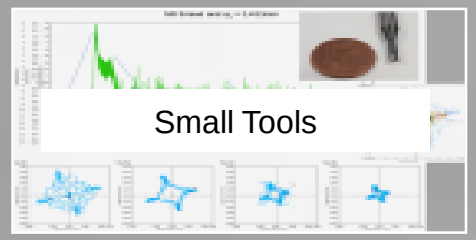
Linear correlation between pressure and axial force

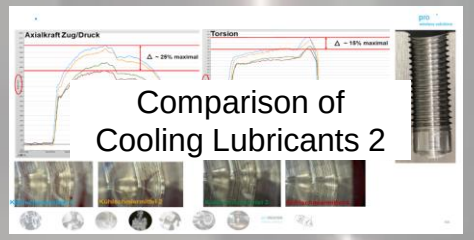
promicron wireless solutions

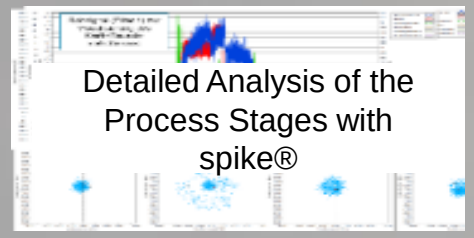
THREADING





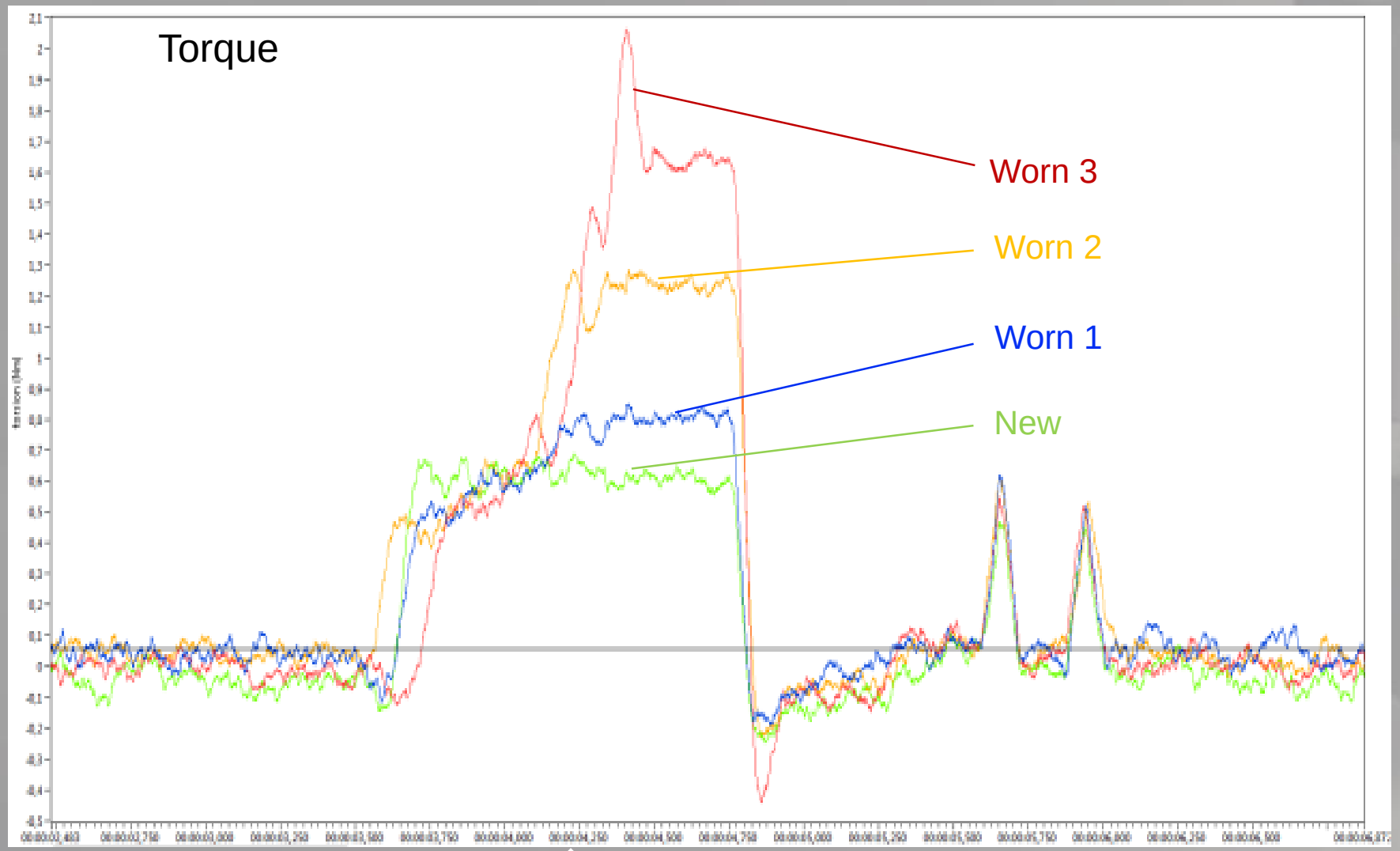




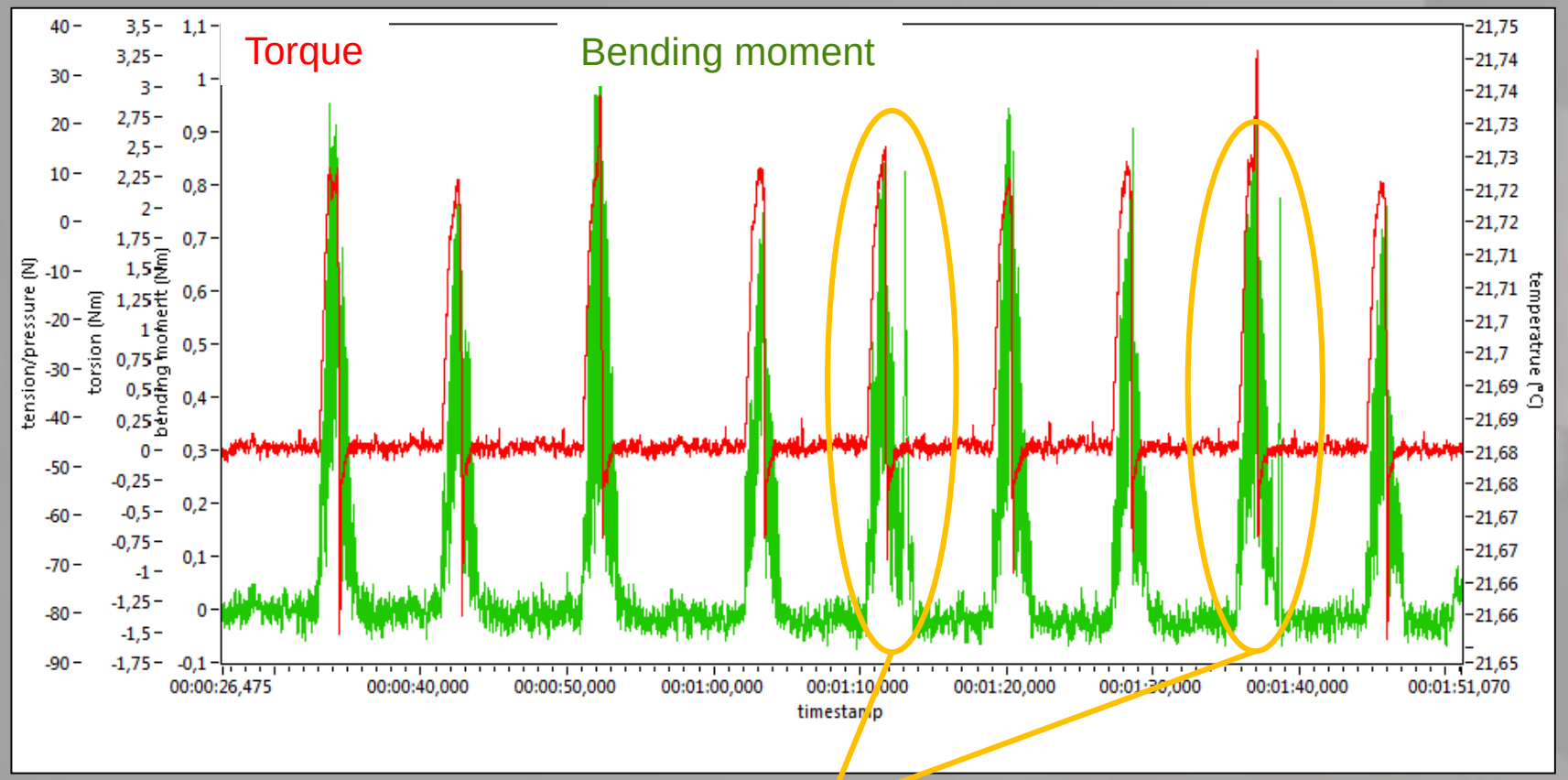


spike® Thread M4

promicron wireless solutions



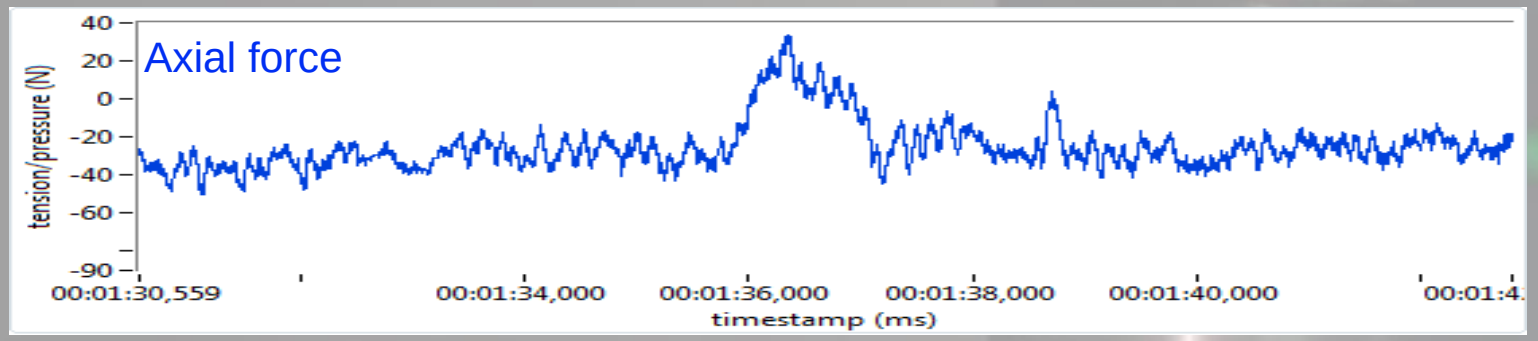
Process Analysis – Measurement of 9 Threading Operations

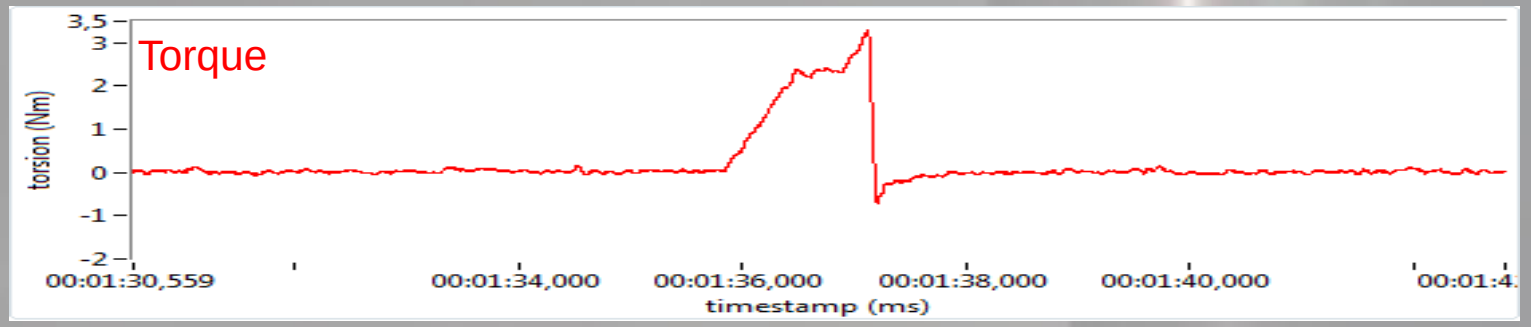


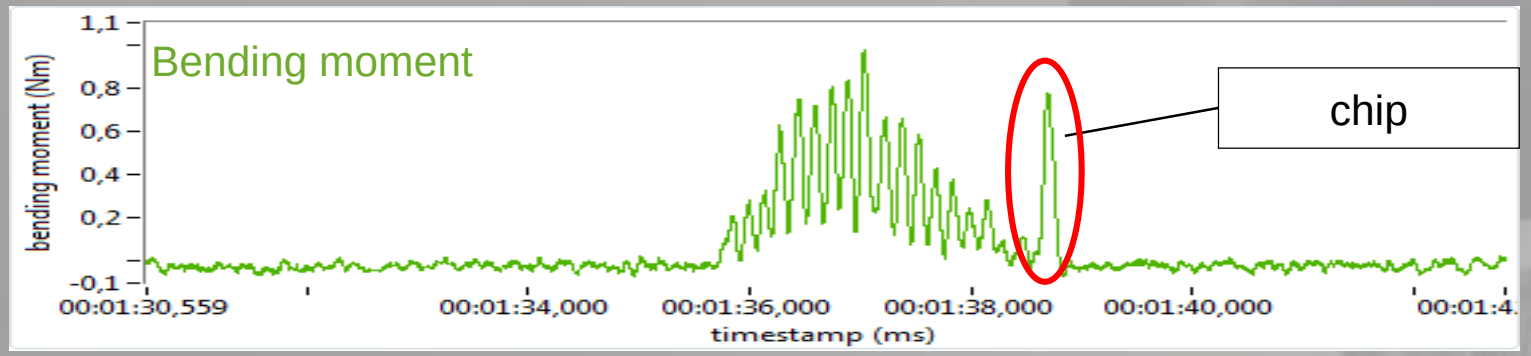
There are visible additional peaks in two threads

Thread M6:

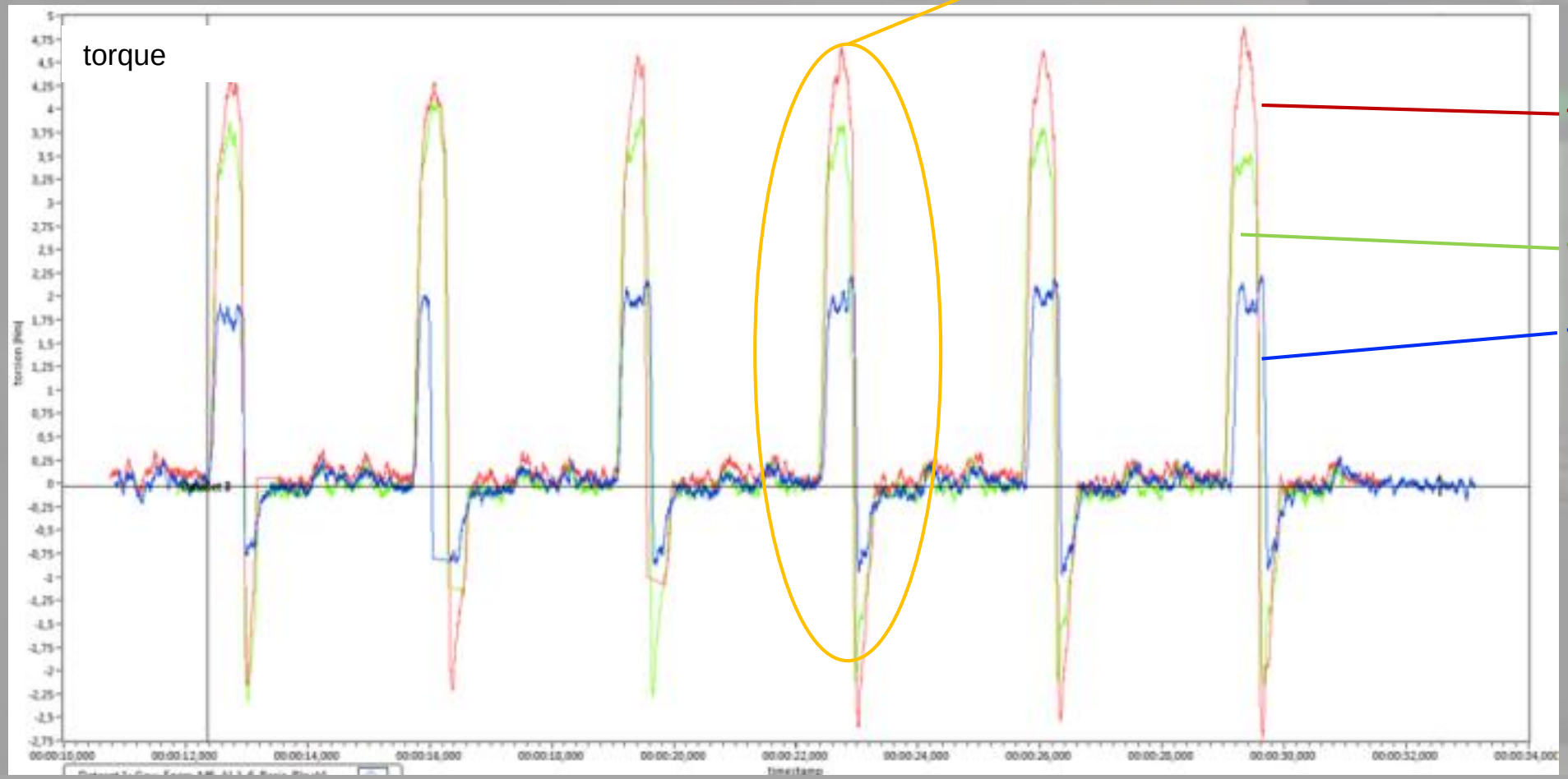
Process analysis – Three different points of view







Comparison of cooling lubricants

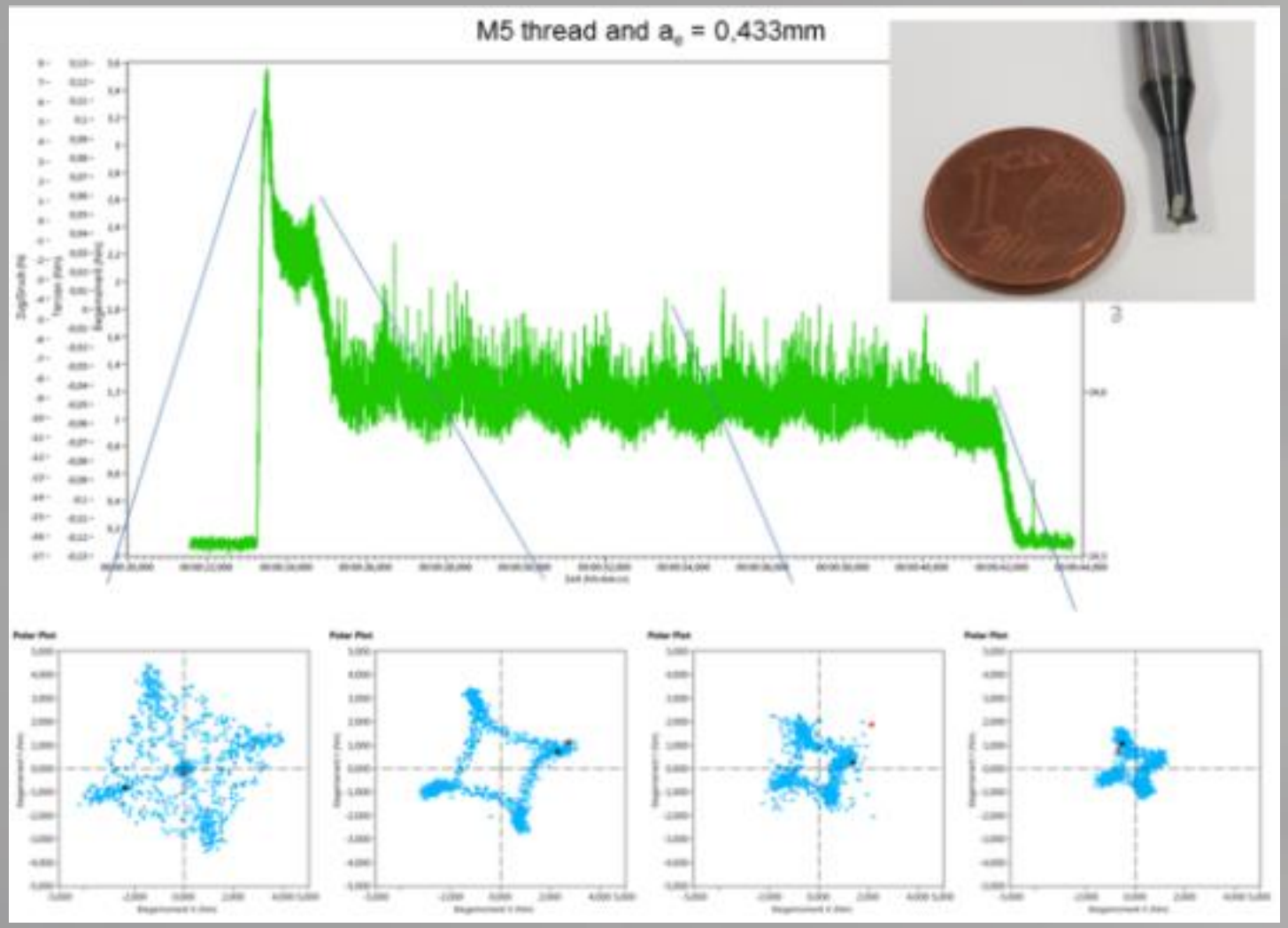


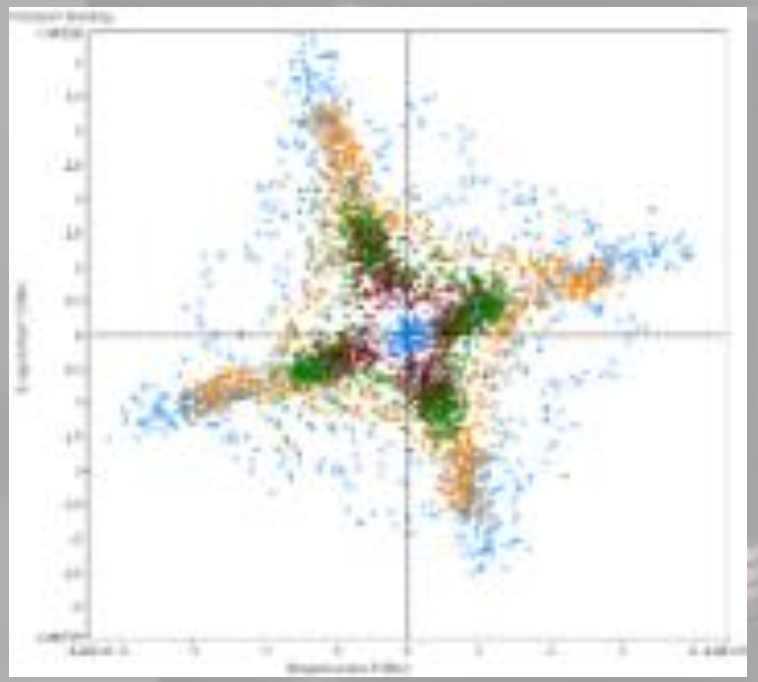
e.g.:
thread tapping

Comparison of different cooling lubricants: different cutting forces of cooling lubricants in torsion measurement visible

spike® Bending moment measurement for small tools

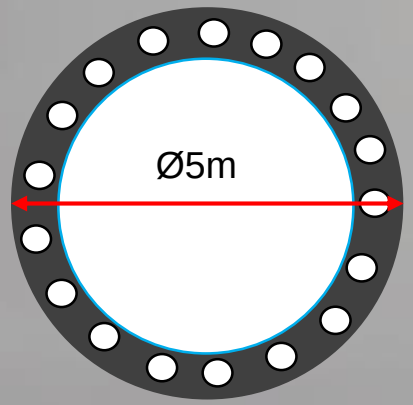
promicron wireless solutions



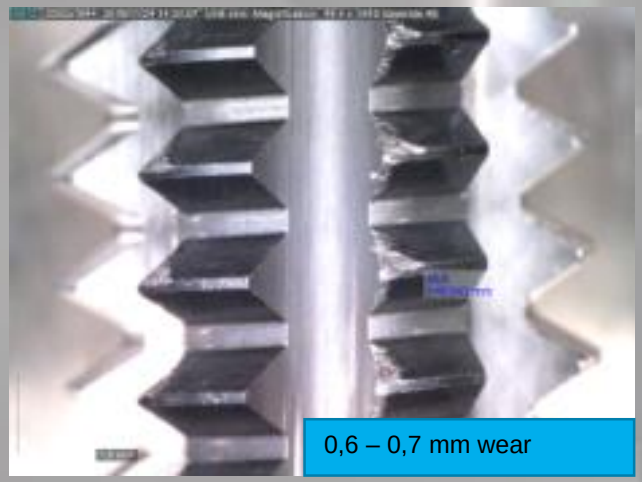


Monitor Thread quality in line production

Last machining step
with 189 threads per ring



The tool can be sharpened



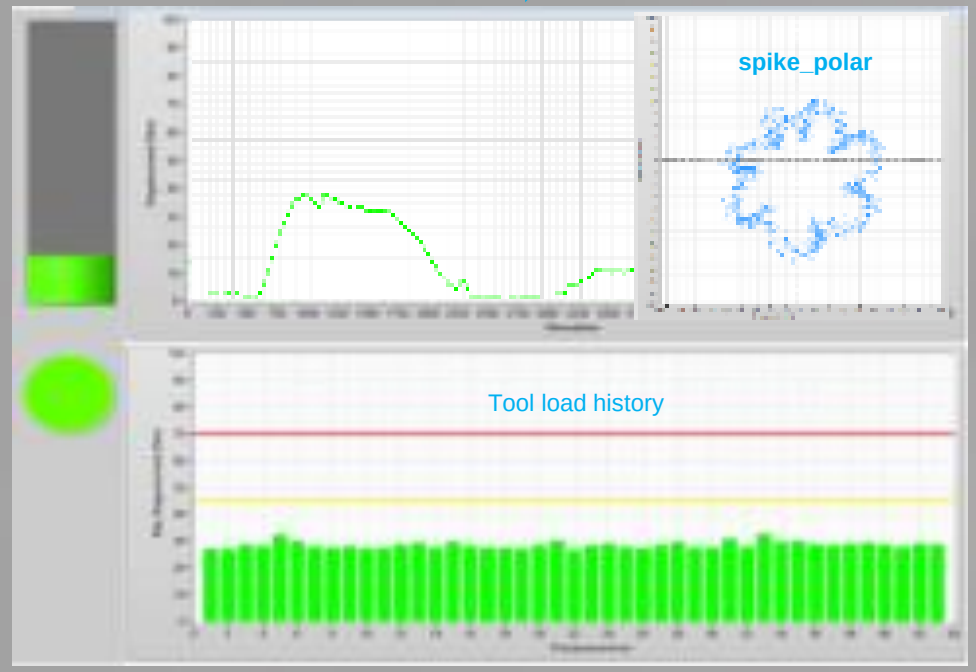
Tool at the end of the service life, leads to inferior quality of thread

Monitor Thread quality in line production

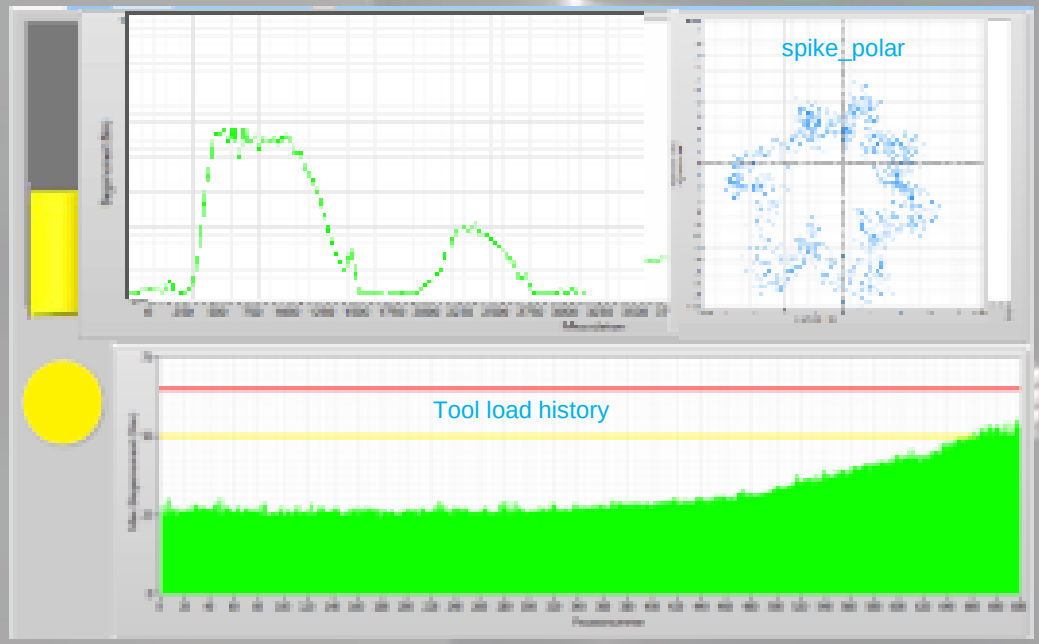
Correlation Wear - Number of Holes Drilled

Monitor Thread quality in line production

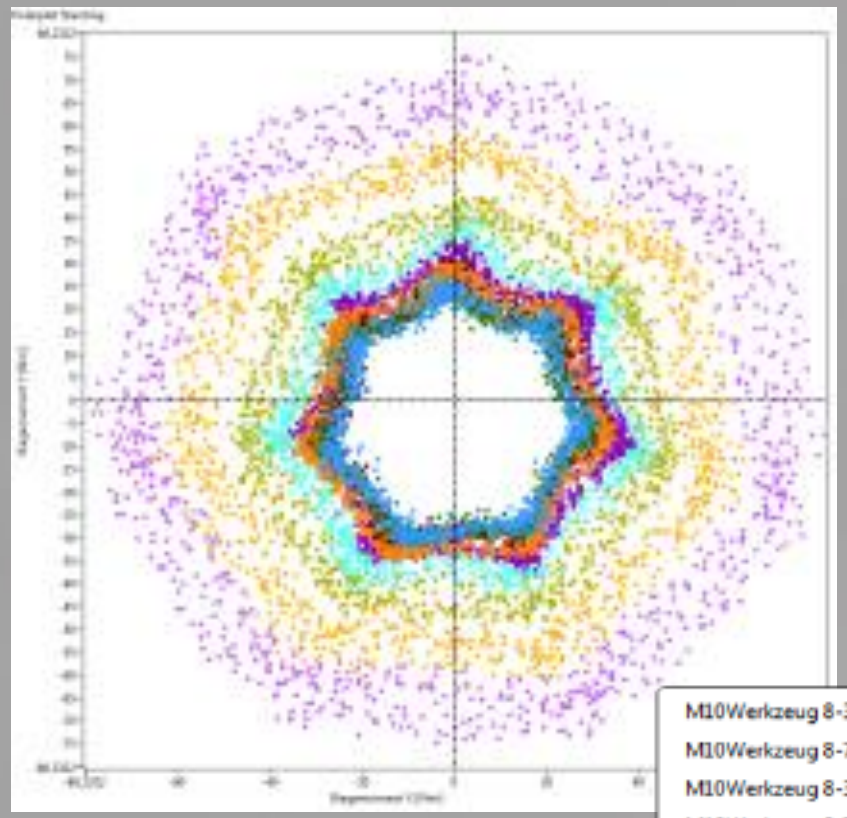
example: after 43 processes → tool still okay

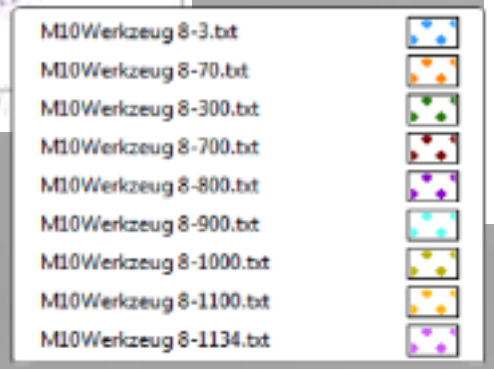


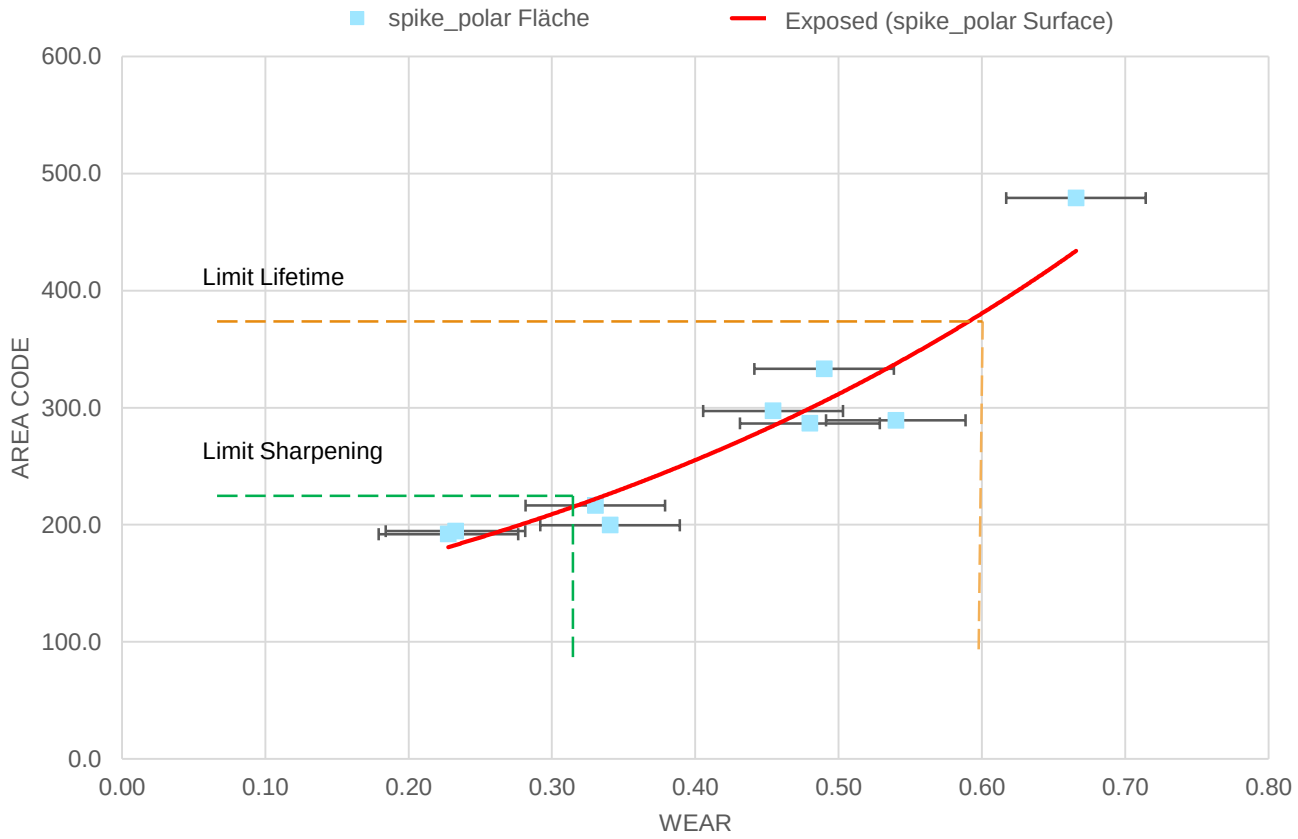
Example: after 690 processes → Warning: tool worn out



Monitor Thread quality in line production

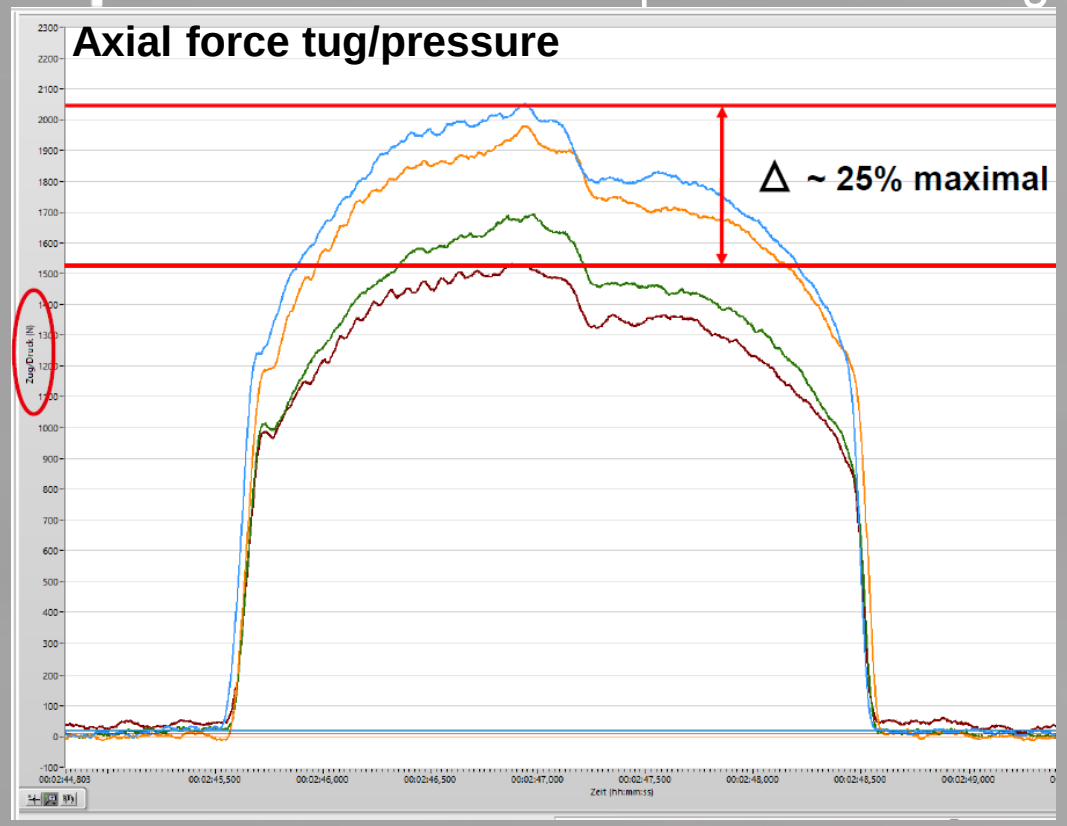


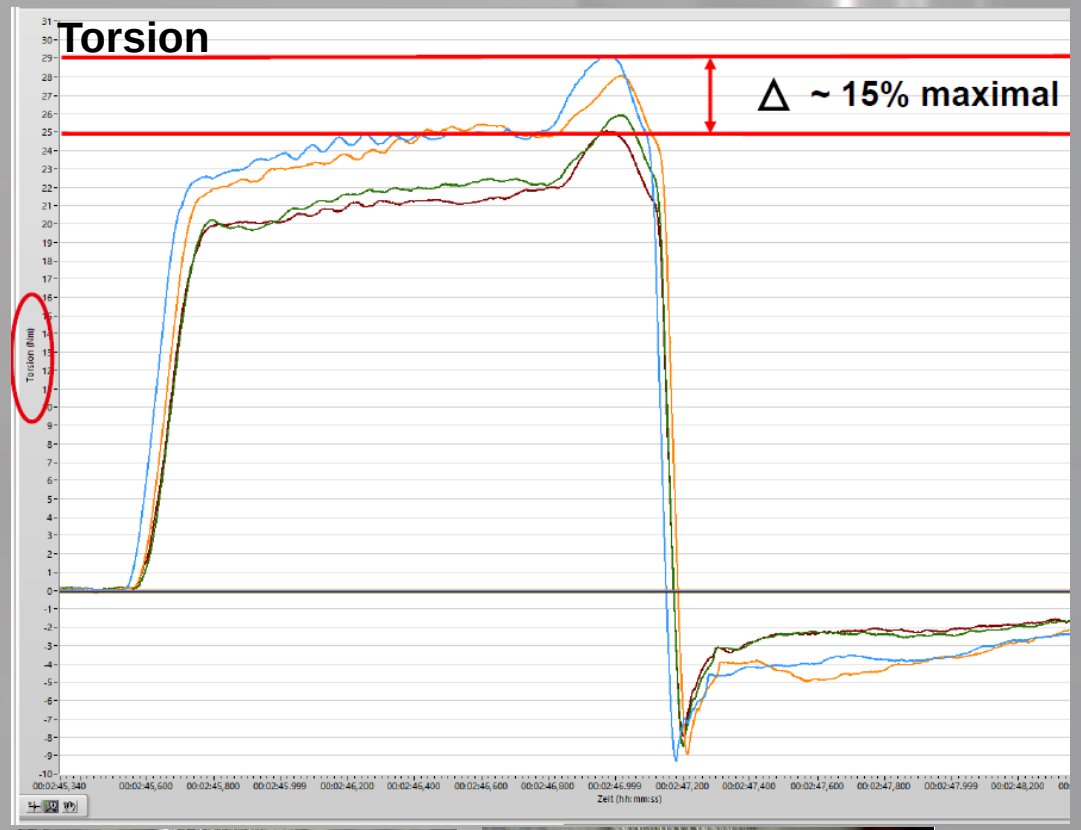


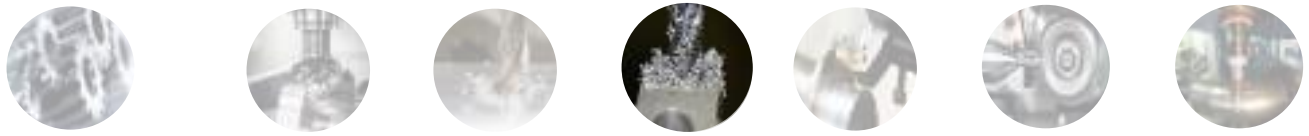


spike® Threads – Comparison of cooling lubricants

promicron wireless solutions

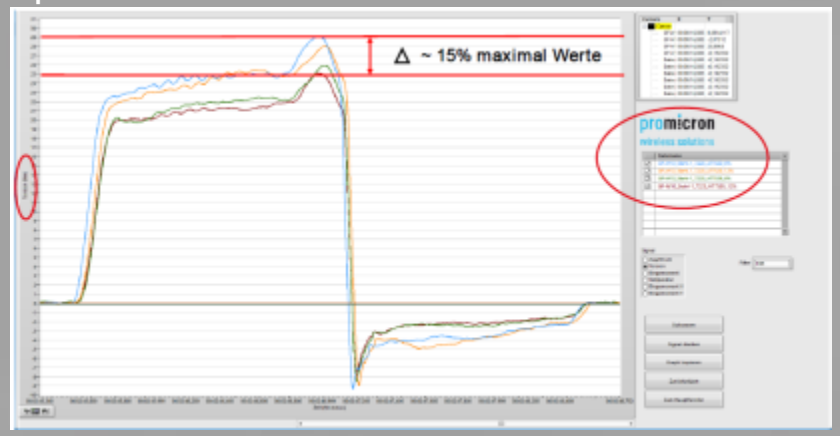




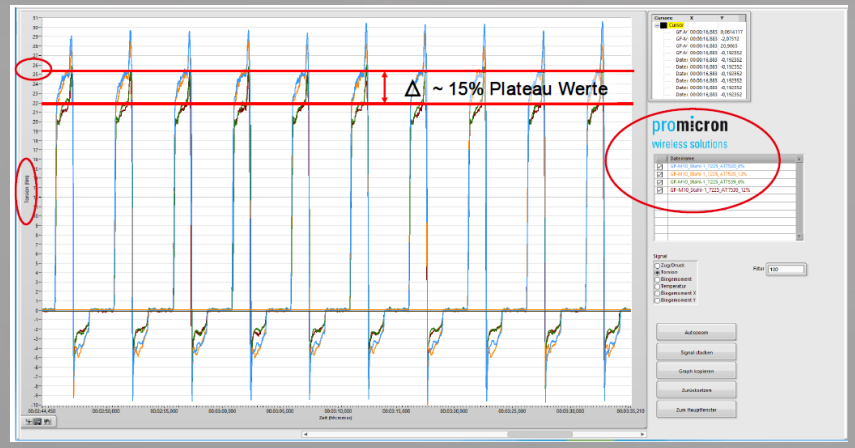


spike® Threads with cooling lubricants

spike – Torsion – blind hole 31

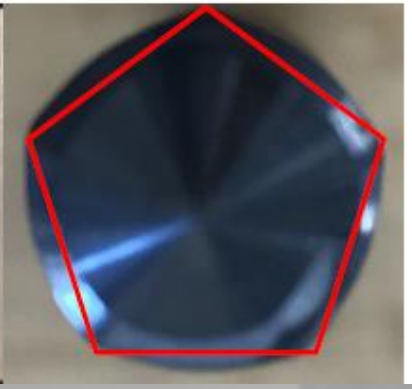


spike – Torsion – clearance holes 31-40



Threads with cooling lubricants

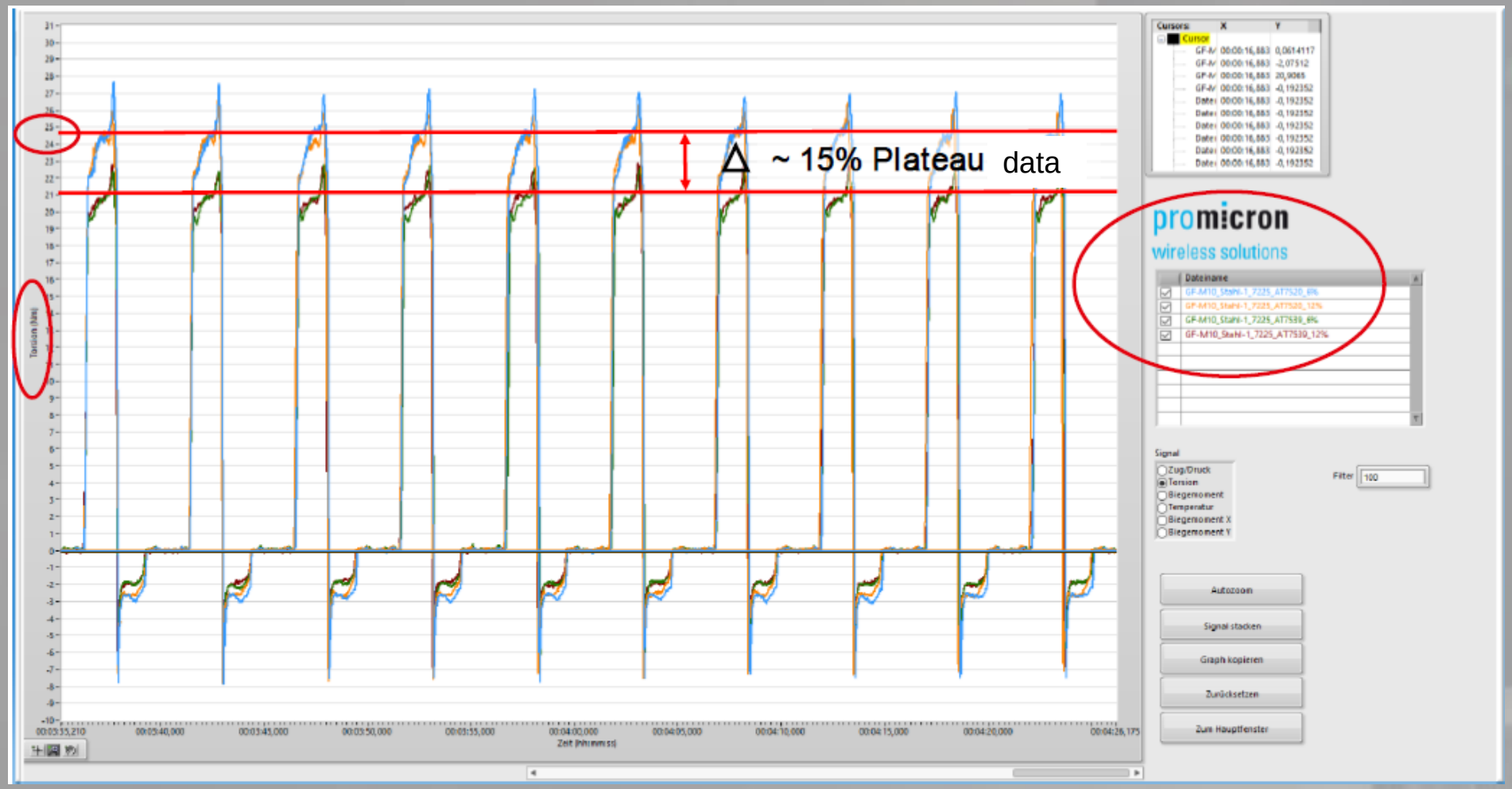
Media:	AquaTec 7520 eligible for easy machining AquaTec 7539 eligible for general machining (6% and 12%)
Material:	Tool steel 1.7225 – 42CrMo4 Breaking stress: 720 N/mm² Hardness: 217HB soft glowed/hardened and tempered
Form tap:	Fraisa M10 Pentagon universal Form tap TiCN coated
Work piece:	20 clearance holes / 30 blind holes
Performance data:	Torsion [Nm] Bending moment [Nm] Tug/Pressure [N]



Spike – Thread forms M10 – 3xd – 50 holes

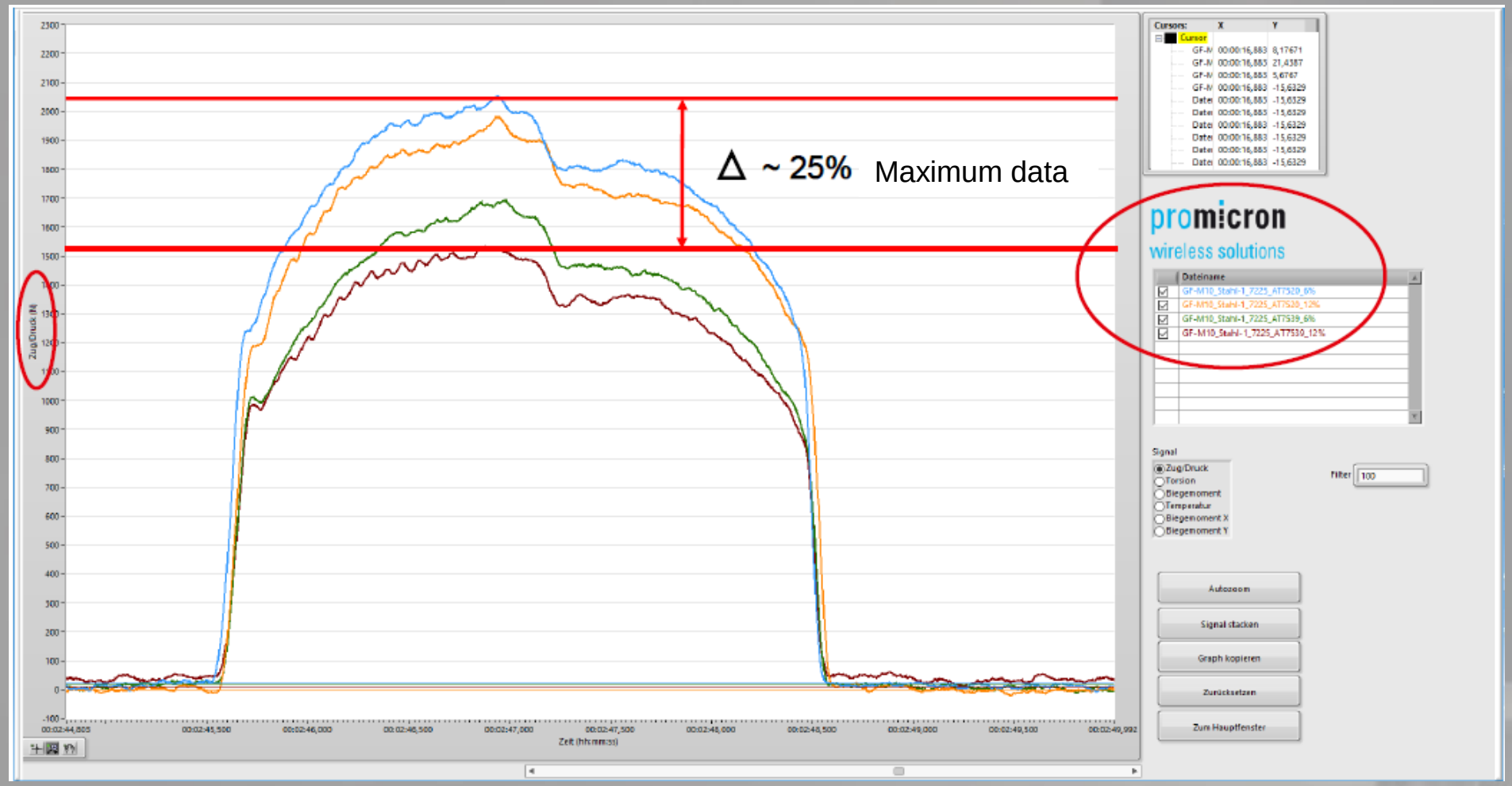
Threads with cooling lubricants

spike – Torsion – blind holes 41-50



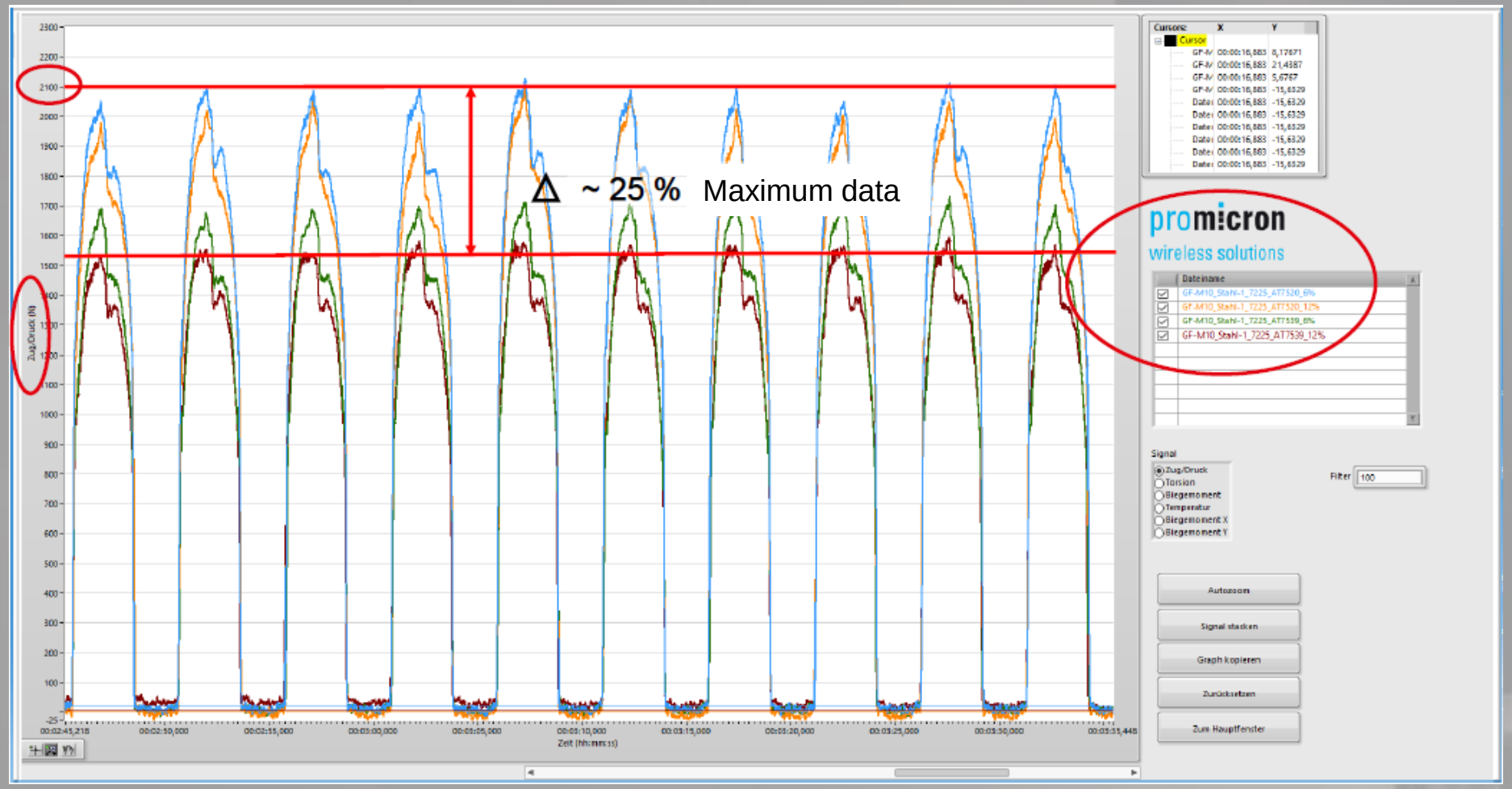
Threads with cooling lubricants

spike – Tug/Pressure – blind hole 31



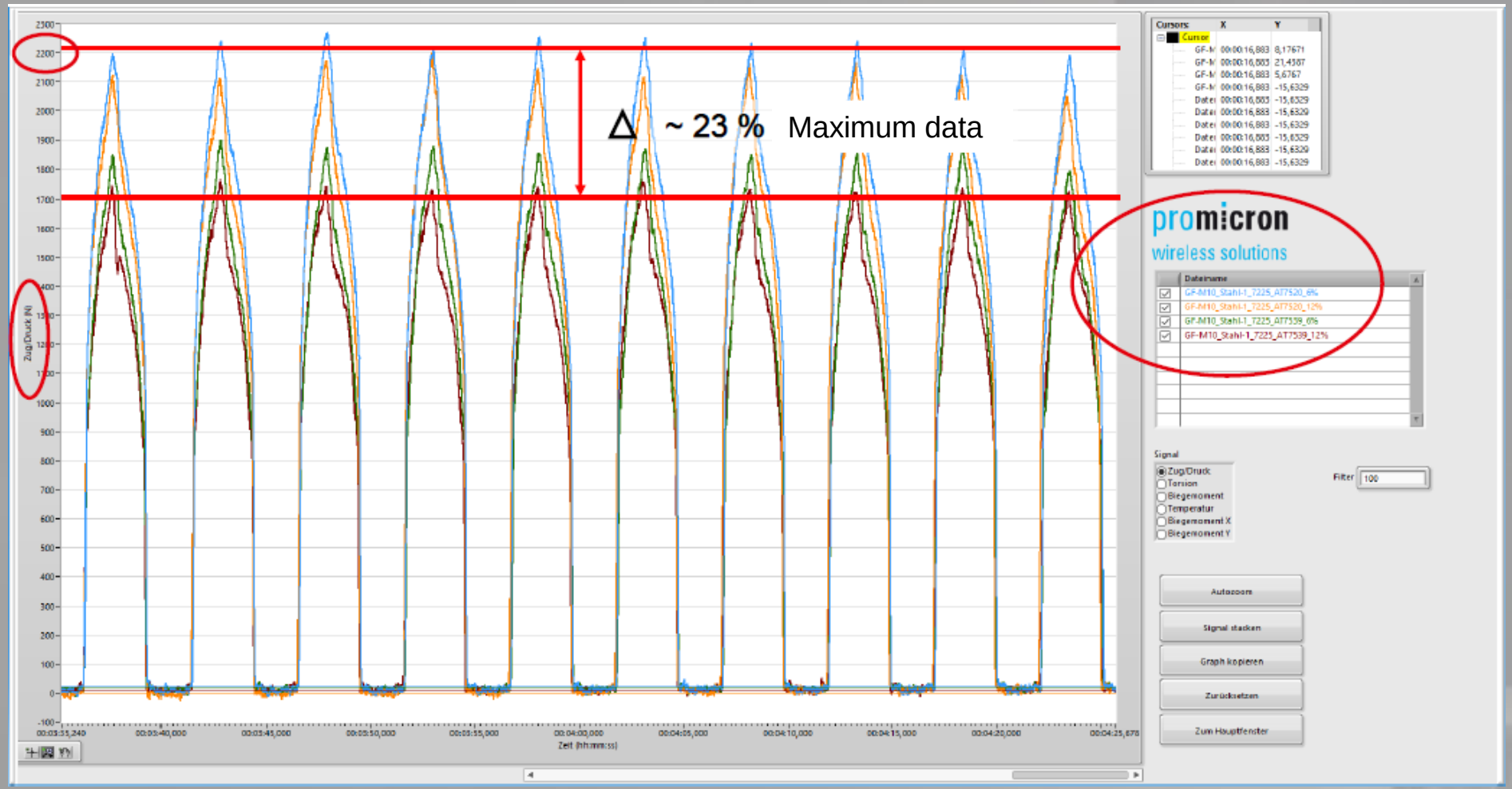
Threads with cooling lubricants

spike – Tug/Pressure – clearance holes 31-40



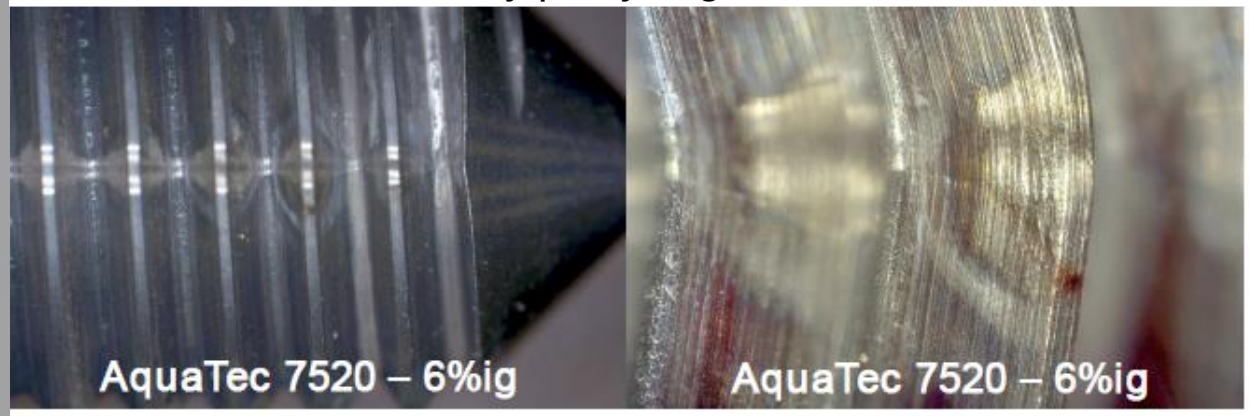
Threads with cooling lubricants

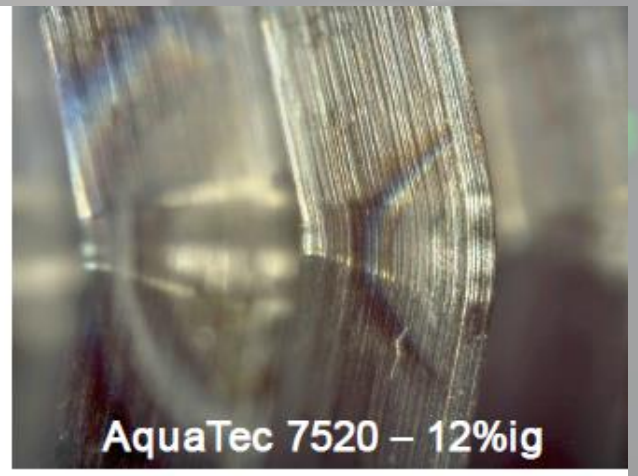
spike – Tug/pressure – blind holes 41-50

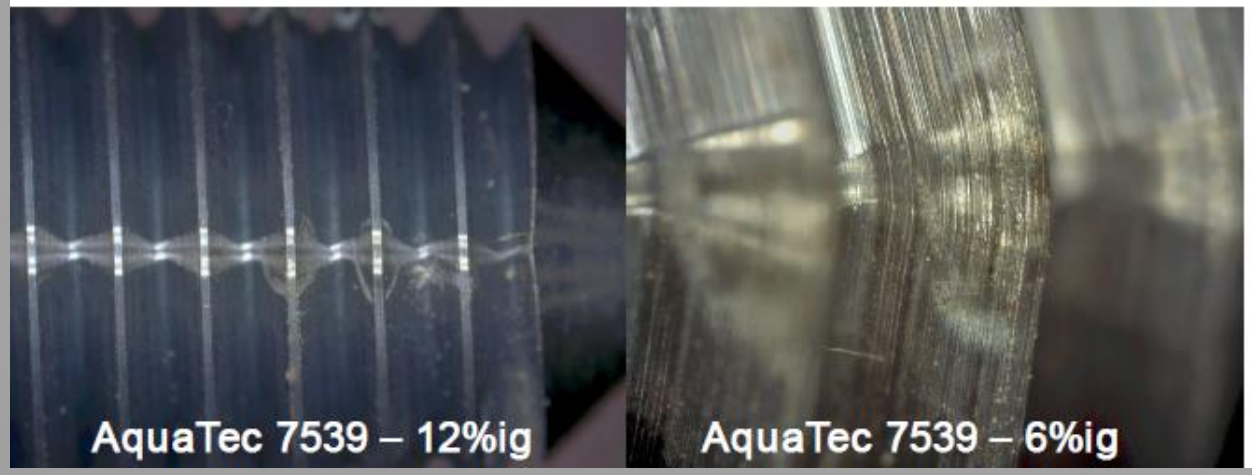


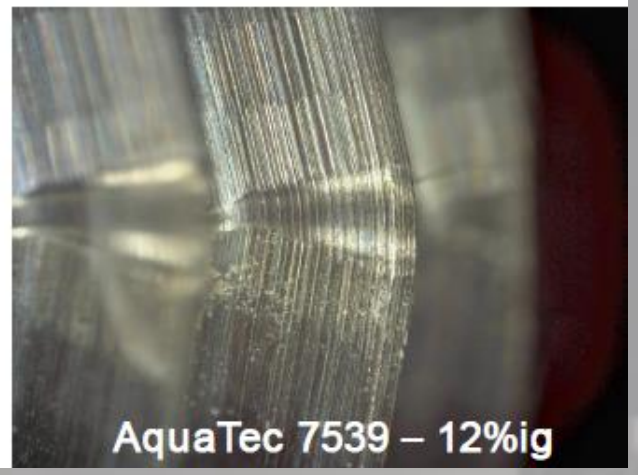
Threads with cooling lubricants

Product is only partly eligible for form tabs







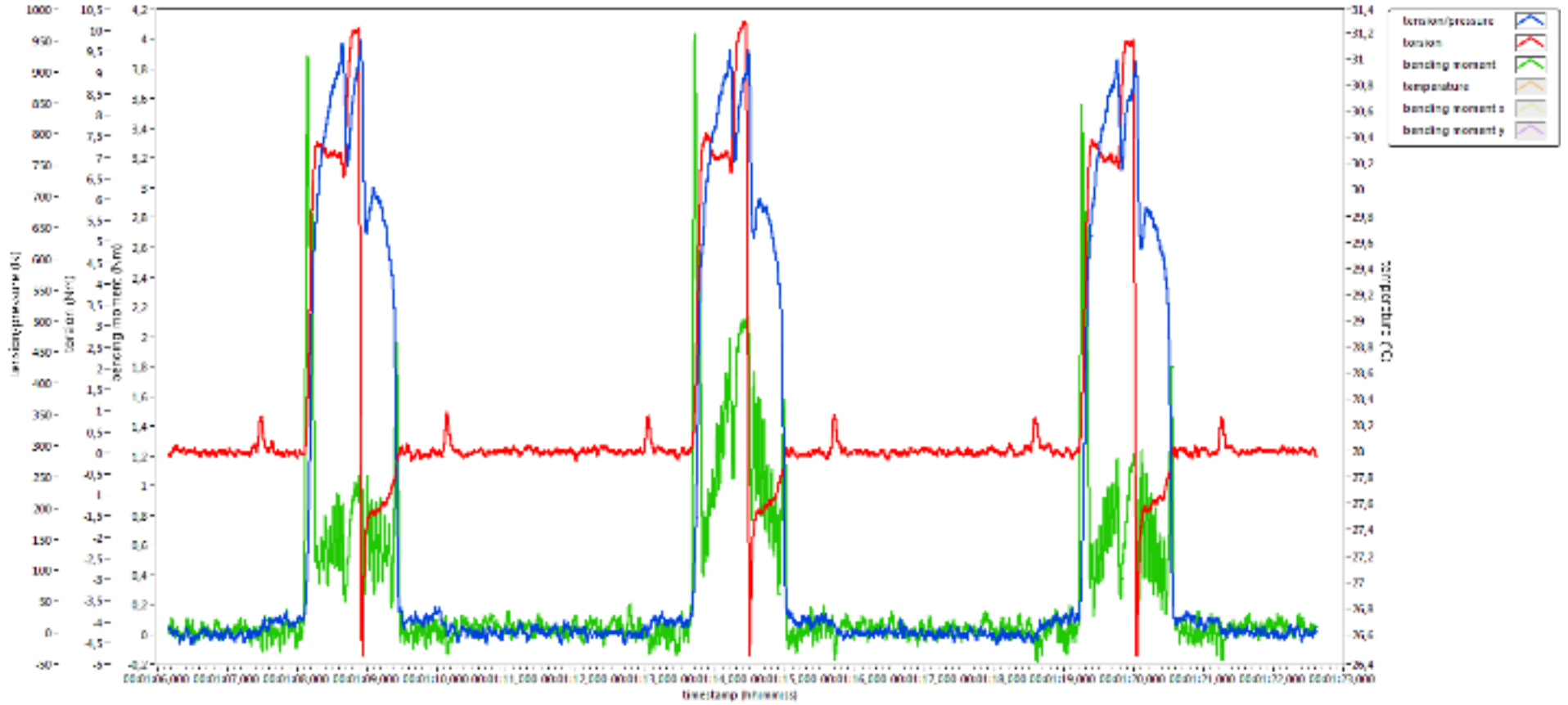


wear on thread former after 50 threads

Tapping – more detailled analysis of single process with spike®

8% concentrate of lubricant
d10, ap20, n1000, vf1500

3 of 24 tapp holes

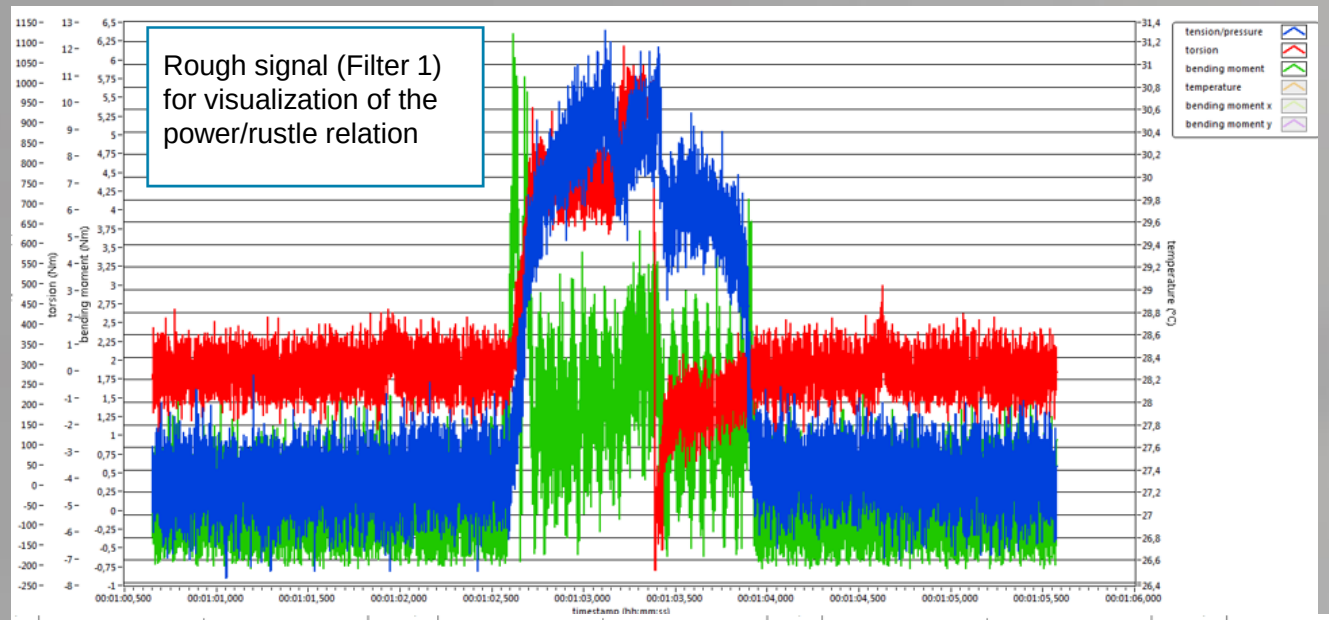


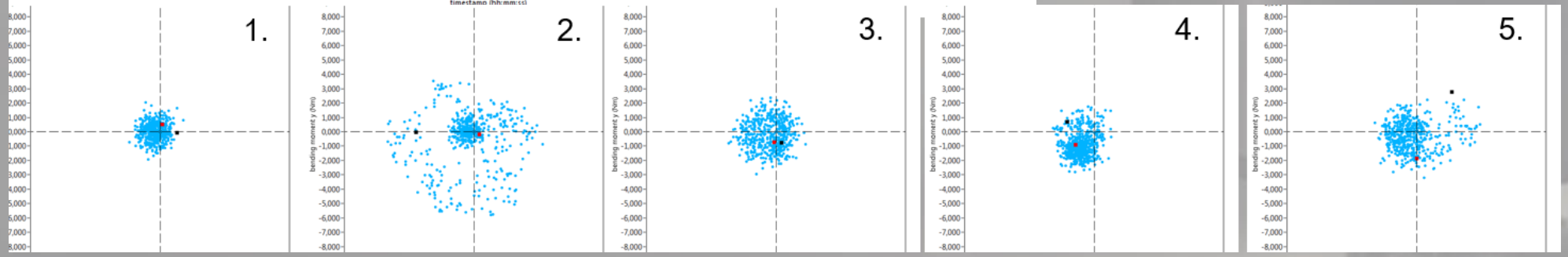
Axial force (feed force)

Torque

Bending moment

Thread cutting – detailed analysis of the process stages with spike®





Process information:

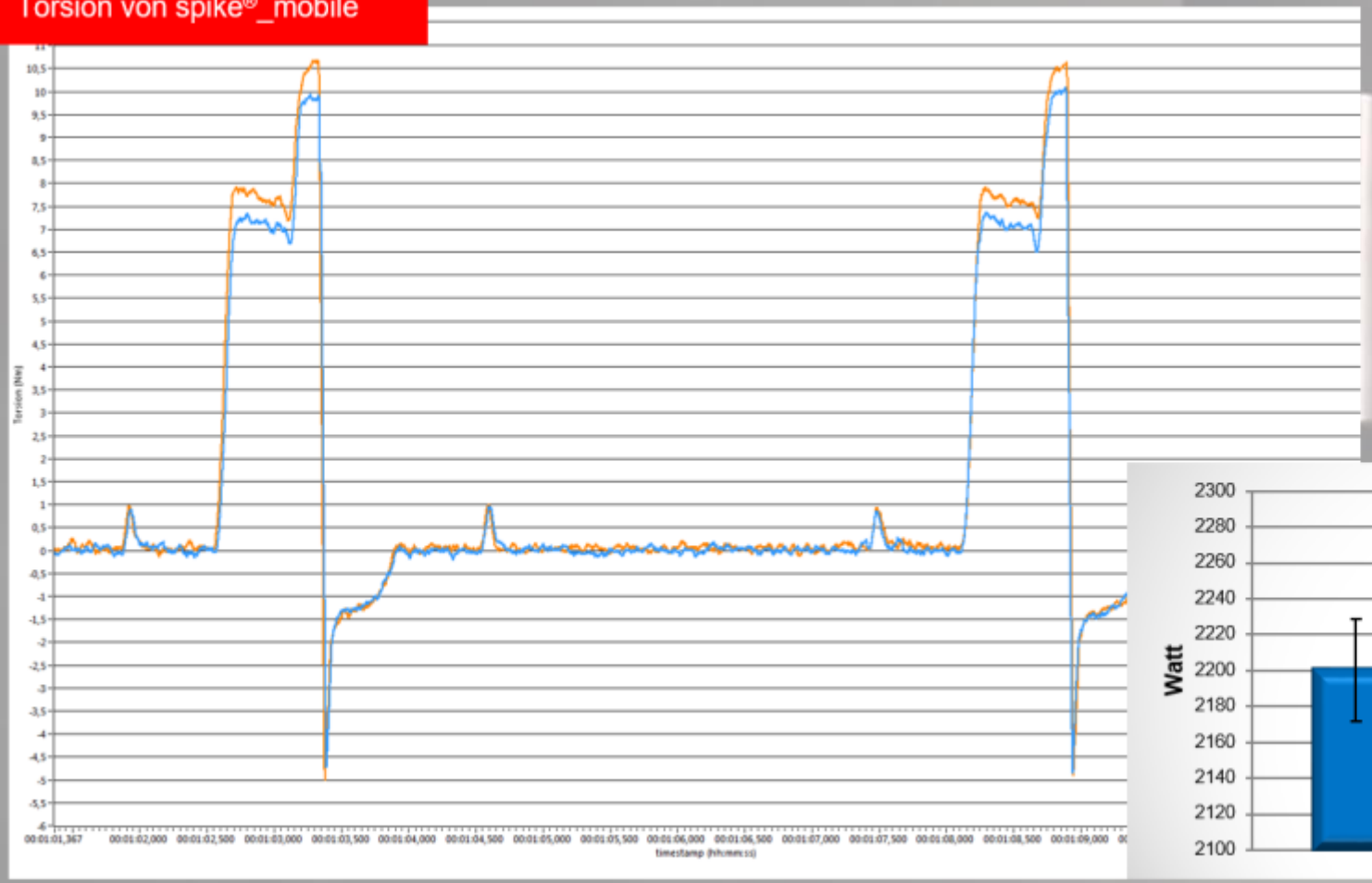
8% Concentrate
d10, ap20, n1000, vf1500

Prozess stages:

1. Idle (on rpm & tared)
2. Spud
3. Thread cutting process
4. Change of cutting direction
5. Spillage
6. Idle (rpm)

Thread cutting – Comparison of cooling lubricants with spike®_TAS

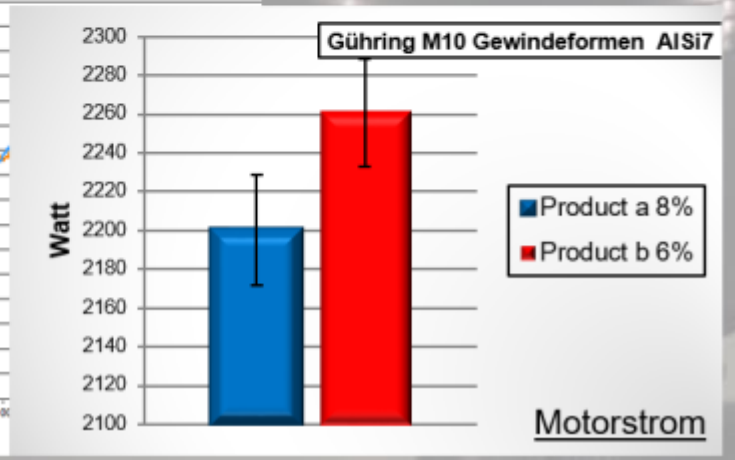
Torsion von spike®_mobile



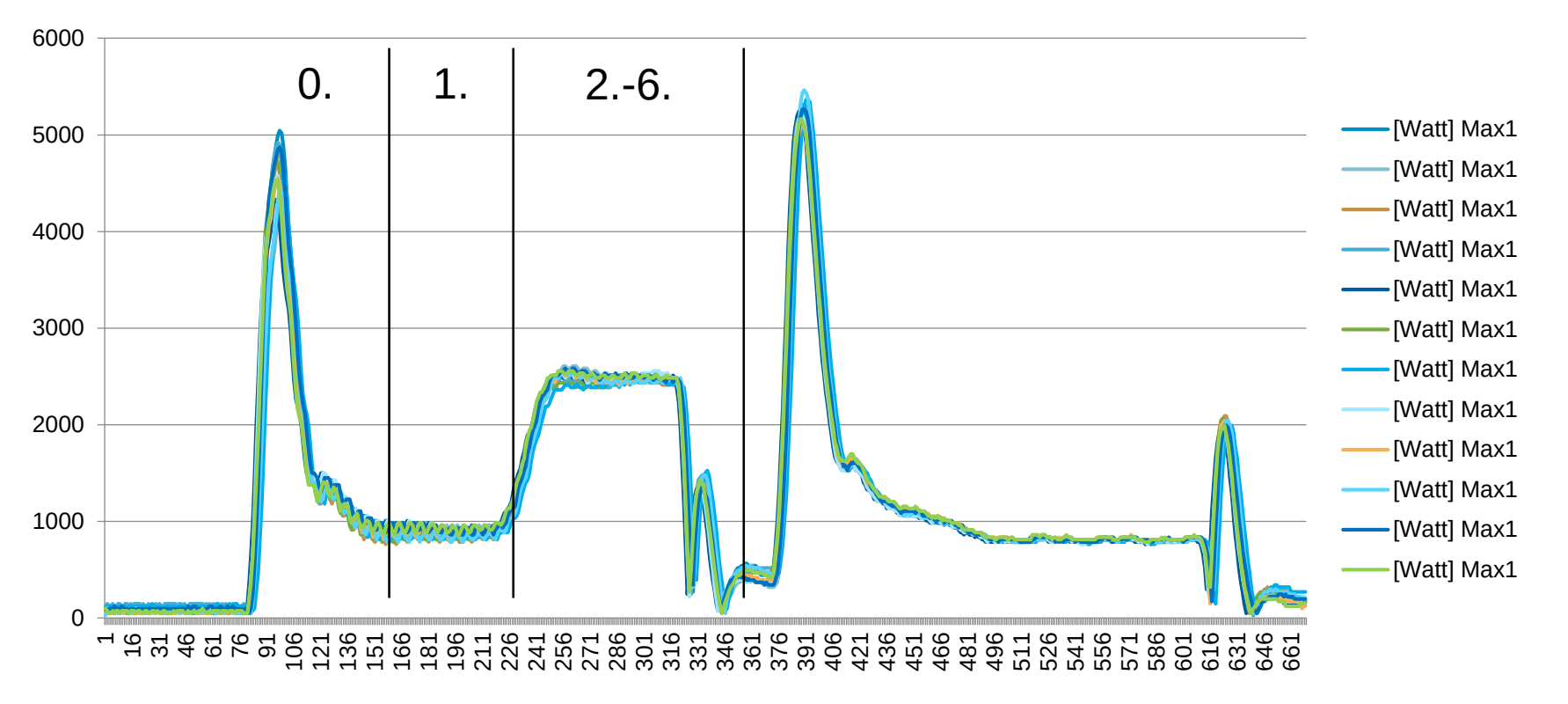
Process information:

8% vs. **6%** Concentrate

bei
d10, ap20, n1000, vf1500



Thread cutting – detailed analysis of the process stages with spindle electricity

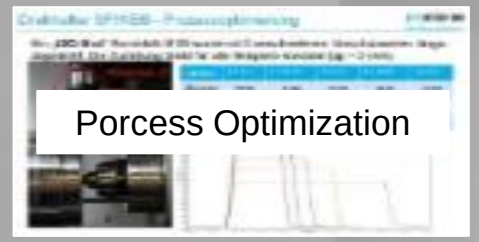


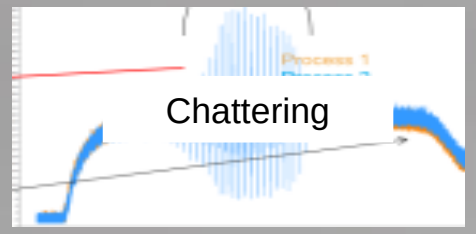
Prozessphasen:

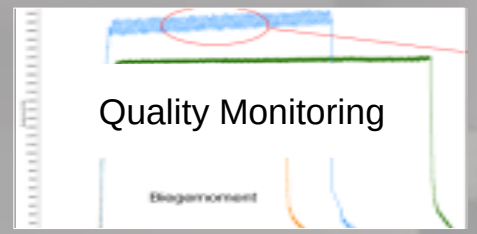
0. rpm An
1. Idle (rpm)
2. Spud
3. Thread cutting process
4. Change of cutting direction
5. Spillage
6. Idle (rpm)

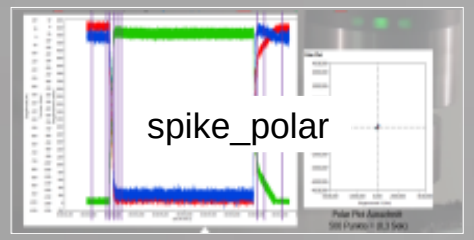
promicron wireless solutions

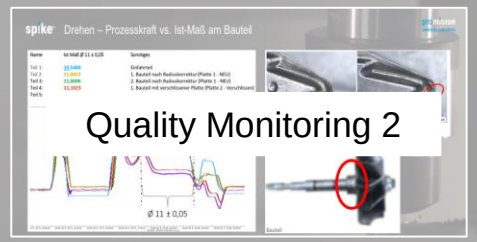
TURNING



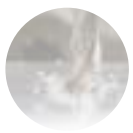
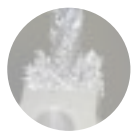
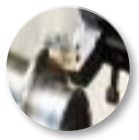






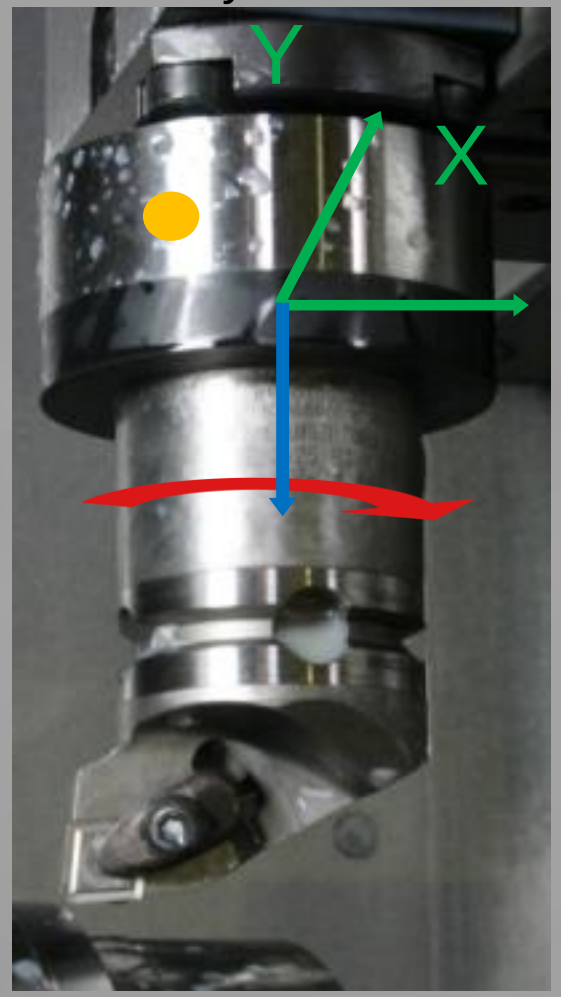




Force and Torque Measurement Directly at the Point of Action

sensory tool holder



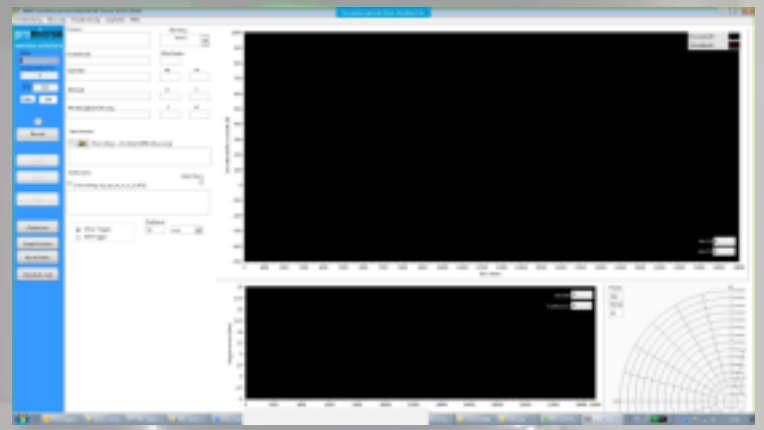
axial force

torsion

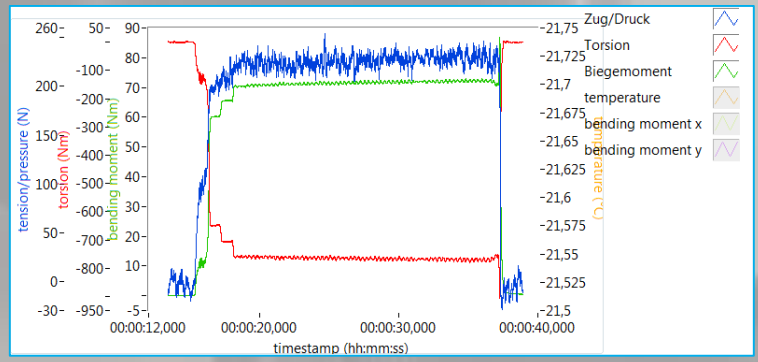
bending moment in x and y direction

temperature

Tool Measurement



Tool Analyser



radio

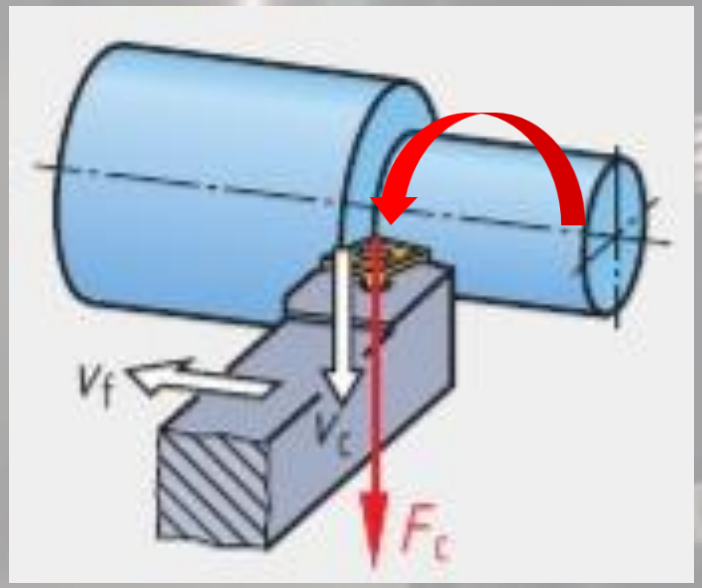
receiver

via USB to PC

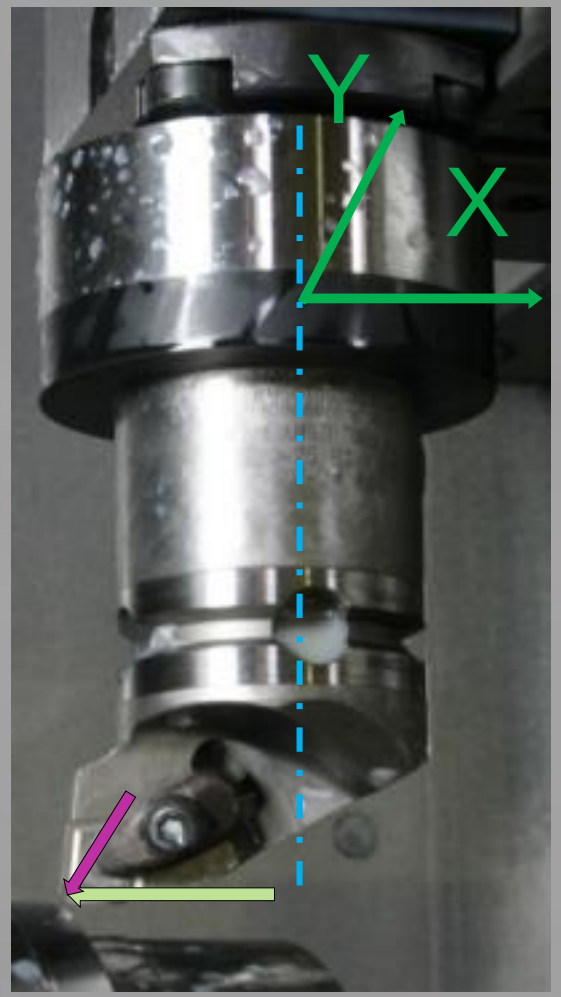
Turning holder spike® - Functionality

The special feature of our **turning holder spike®** is that the calculated **cutting force Fc** can also be displayed with it!

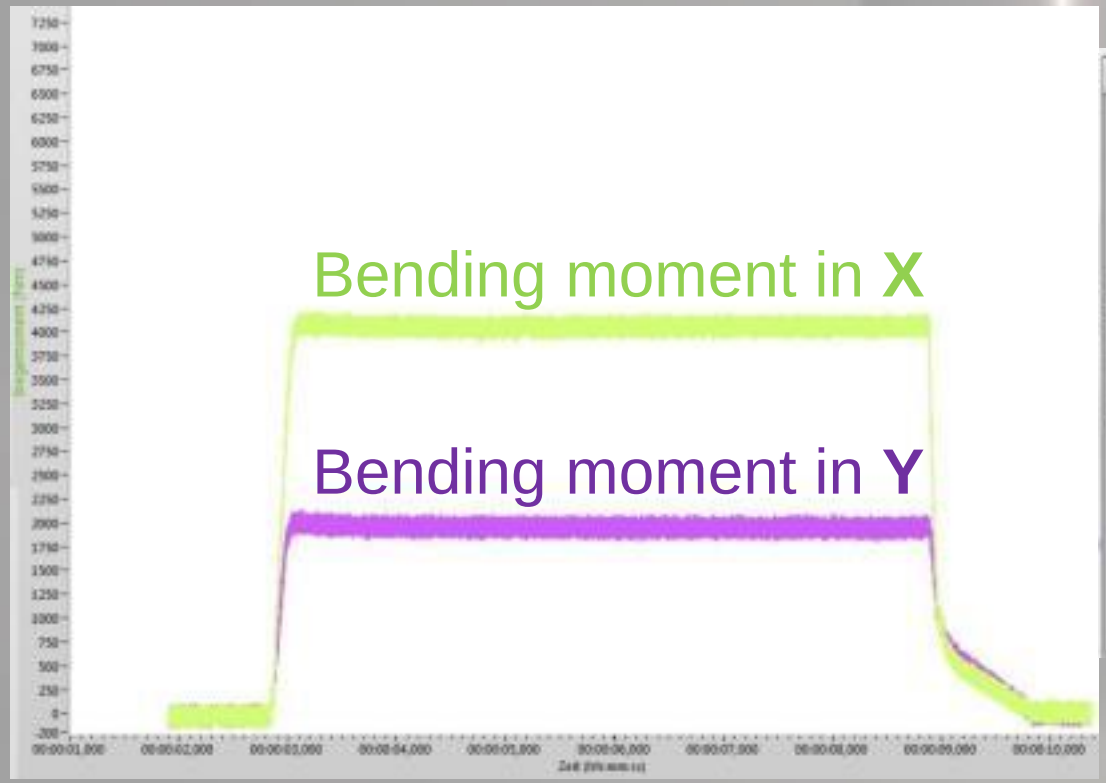
$$F_c = \frac{\text{Torsion}}{r}$$

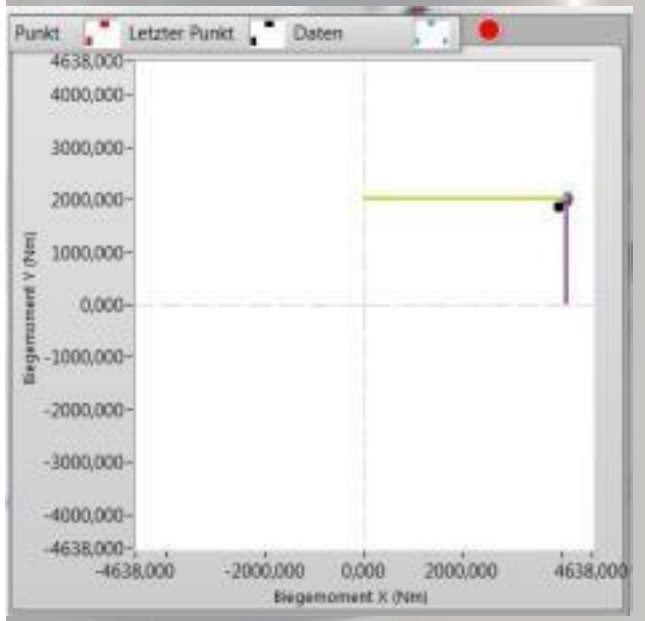


Turning holder spike® - Functionality



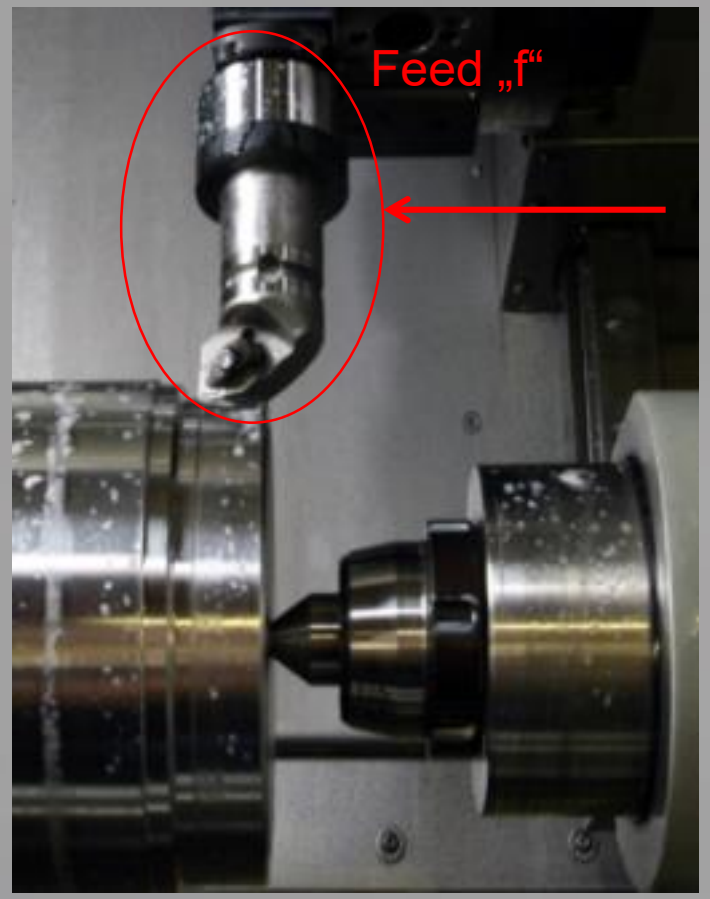
Another special feature of our torsion holder spike® is that the bending moment is displayed in X and Y direction with the spike_polar!



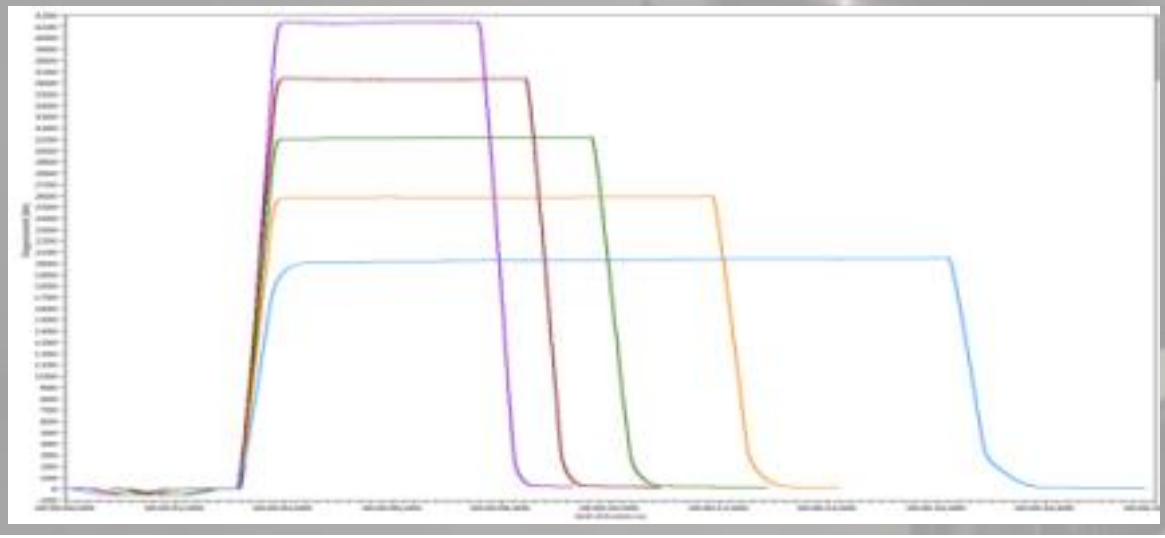


Turning holder spike® - Process optimization

A "42CrMo4" round steel bar Ø 68 was turned lengthwise with 5 different feed values. The infeed remains constant for all examples (ap = 2 mm).

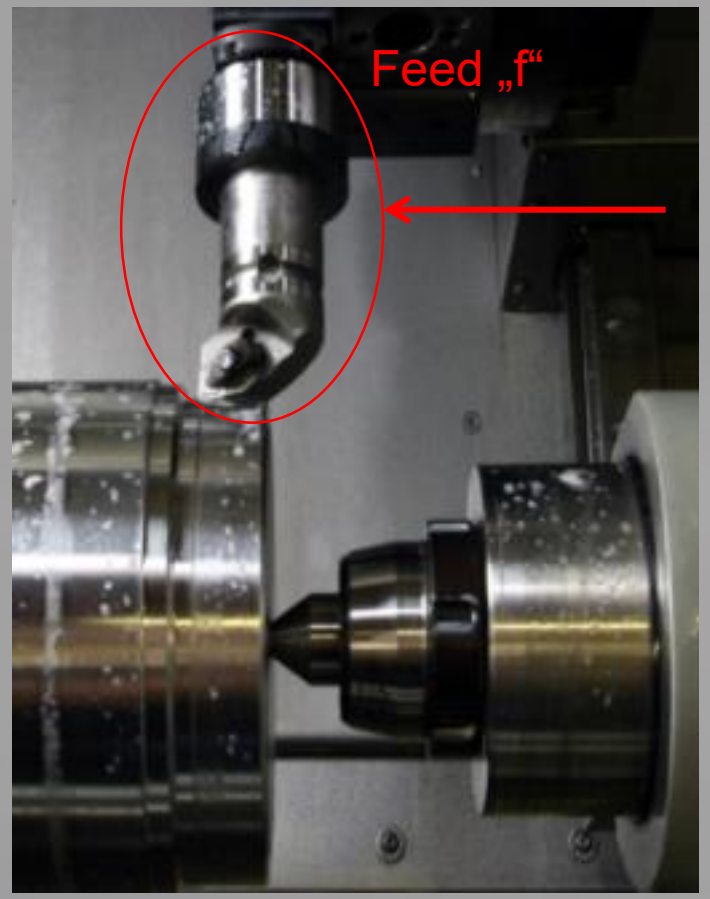


mm/U	f = 0,1	f = 0,15	f = 0,2	f = 0,25	f = 0,3
Mmax(Nm)	2030	2590	3120	3650	4150
Δ „f“		50%	100%	150 %	200%
Δ „Mmax“		27,6%	53,7%	79,8%	104,4%



Turning holder spike® - Process optimization

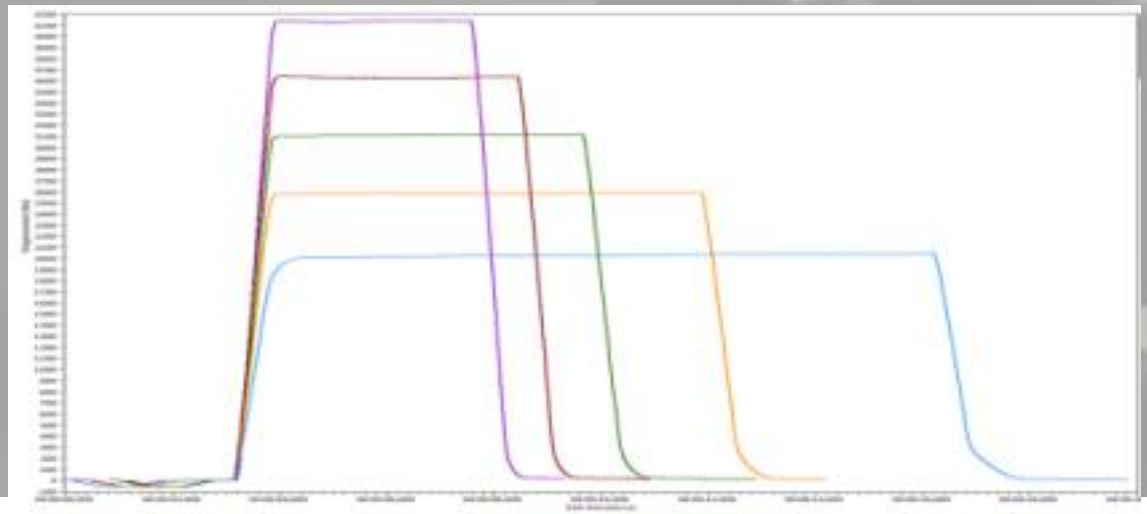
A "42CrMo4" round steel bar Ø 68 was turned lengthwise with 5 different feed values. The infeed remains constant for all examples (ap = 2 mm).



50% 100% 150% 200%

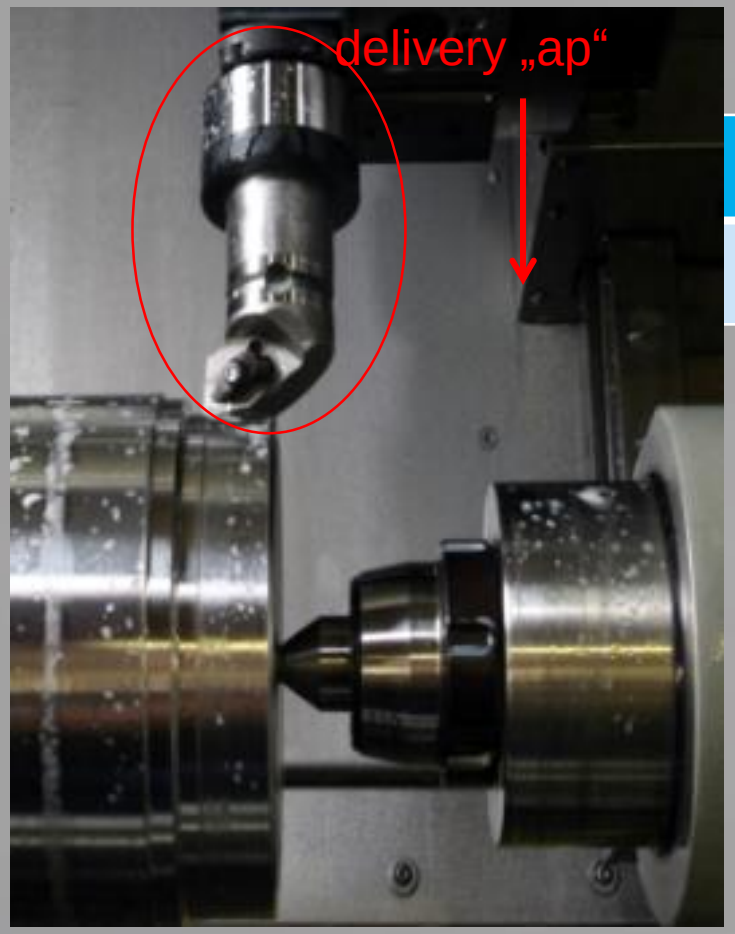
mm/U	f = 0,1	f = 0,15	f = 0,2	f = 0,25	f = 0,3
Mmax(Nm)	2030	2590	3120	3650	4150

27,6% 53,7% 79,8% 104,4%



Turning holder spike® - Process optimization

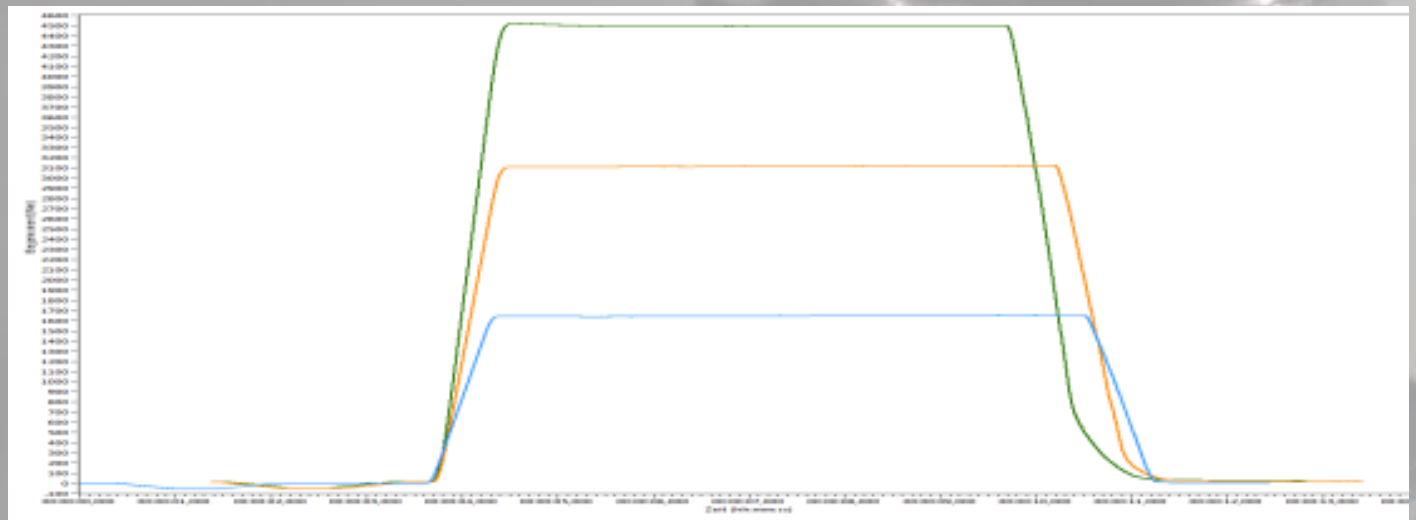
A "**42CrMo4**" round steel bar Ø 68 was turned lengthwise with 3 different infeeds. The feed rate remains constant for all examples (fU = 0.2 mm/rev).



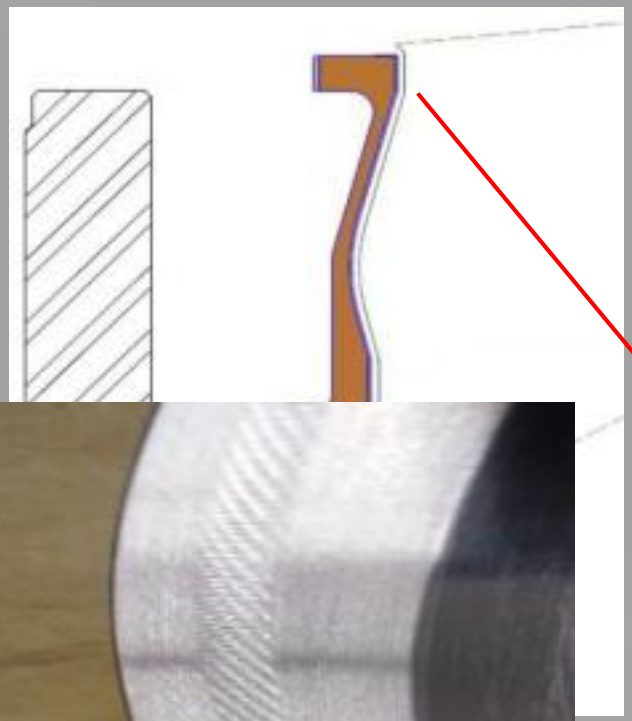
100% 200%

(mm)	ap = 1	ap = 2	ap = 3
Mmax (Nm)	1650	3110	4500

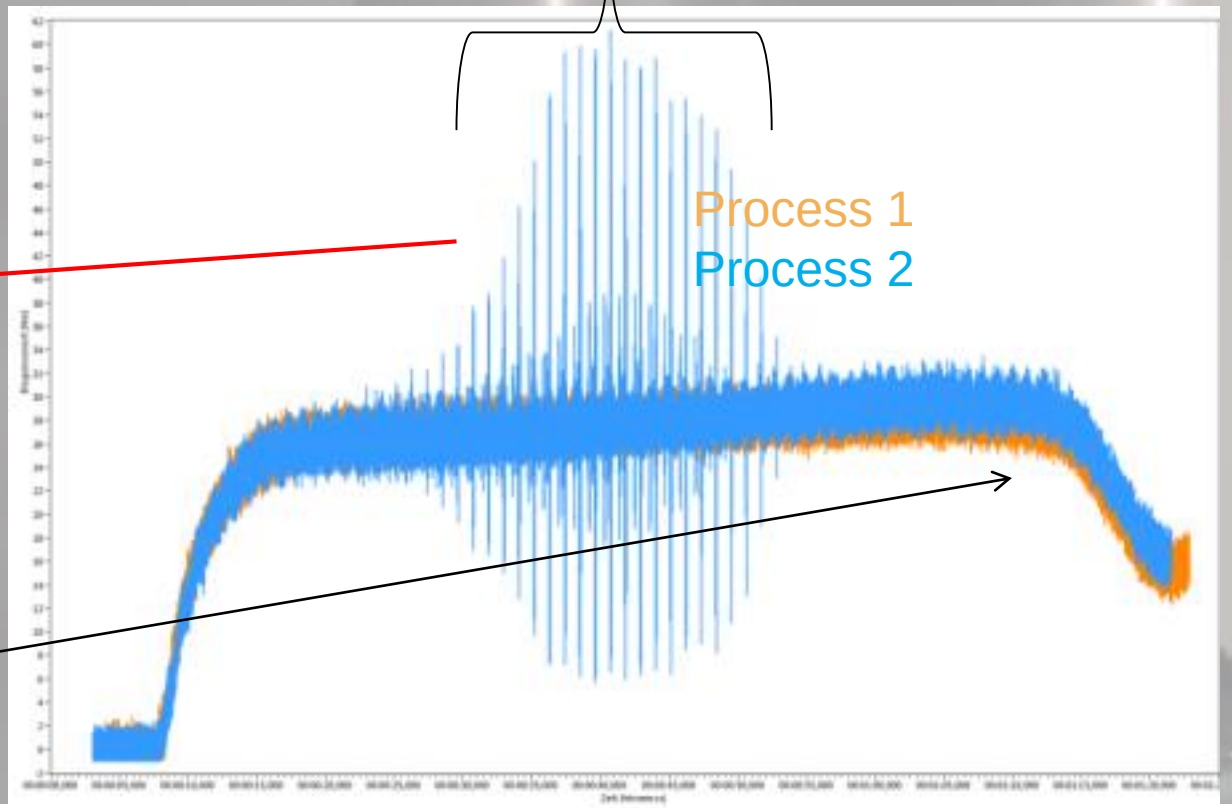
88,5% 172,7%



spike® Truning - Chattering



Chattering (6 to 58 Nm)
- normal process 30 Nm -

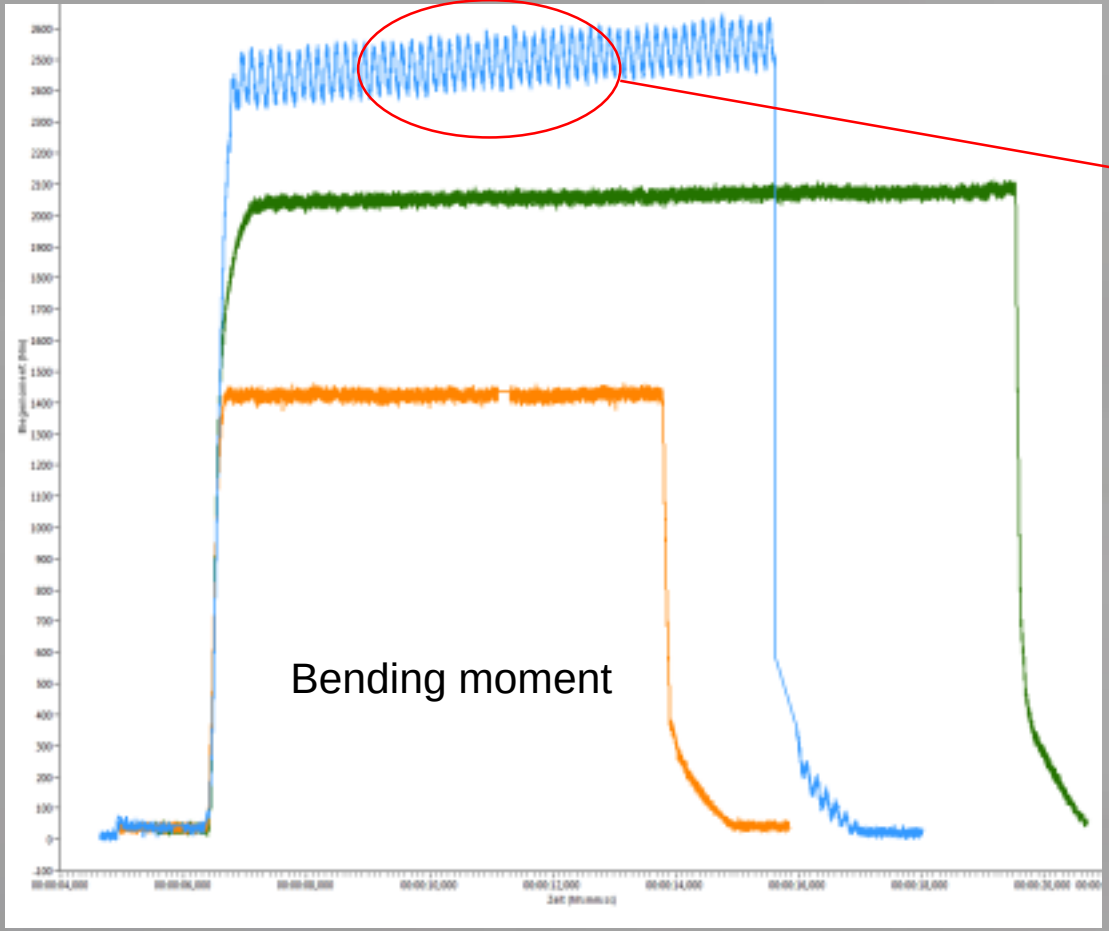


more wear after chattering

spike® Turning holder spike®-Process optimization

promicron wireless solutions

Three different materials „ **Inconel718** / **42CrMo4** / **Ti6424**“were turned lengthwise with the same feed and feed values (ap = 2 mm / f = 0.1 mm/rev).

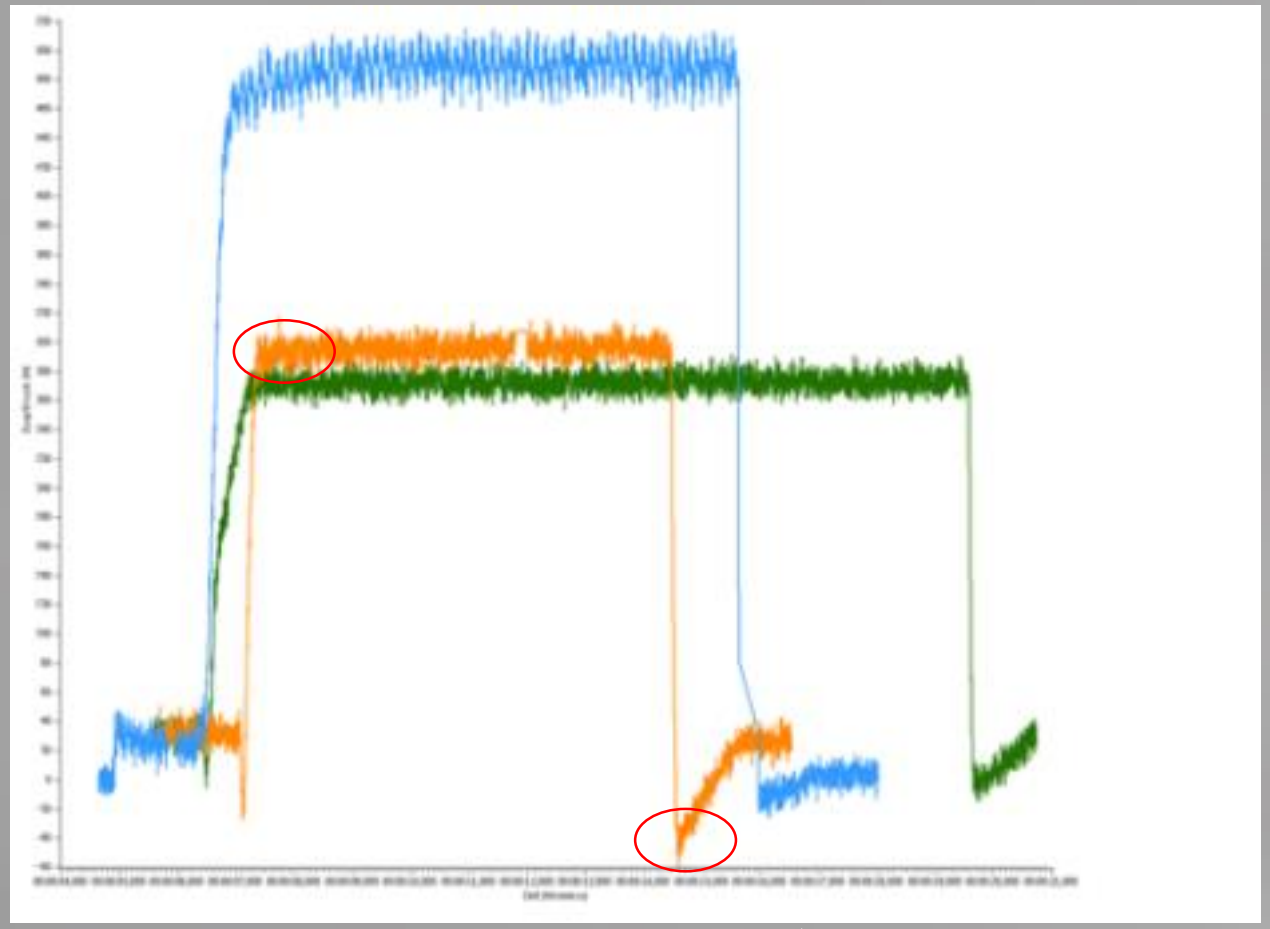


Mmax: **2500 Nm** / **2030 Nm** / **1360 Nm**

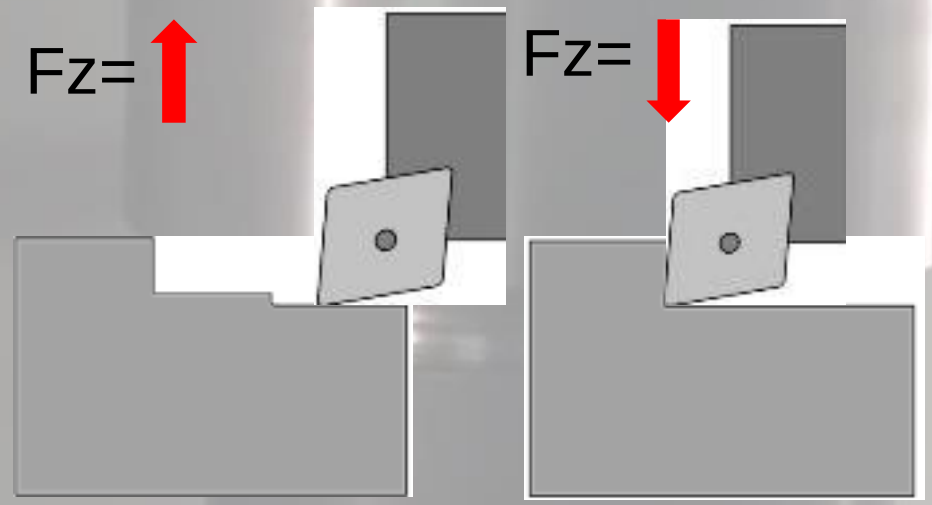
When comparing the bending moment, the **vibrations** that occur during the machining process of the **"Inconel718"** can be seen!

Turning holder spike® - Process optimization

Three different materials „ **Inconel718** / **42CrMo4** / **Ti6424**“were turned lengthwise with the same feed and feed values (ap = 2 mm / f = 0.1 mm/rev).



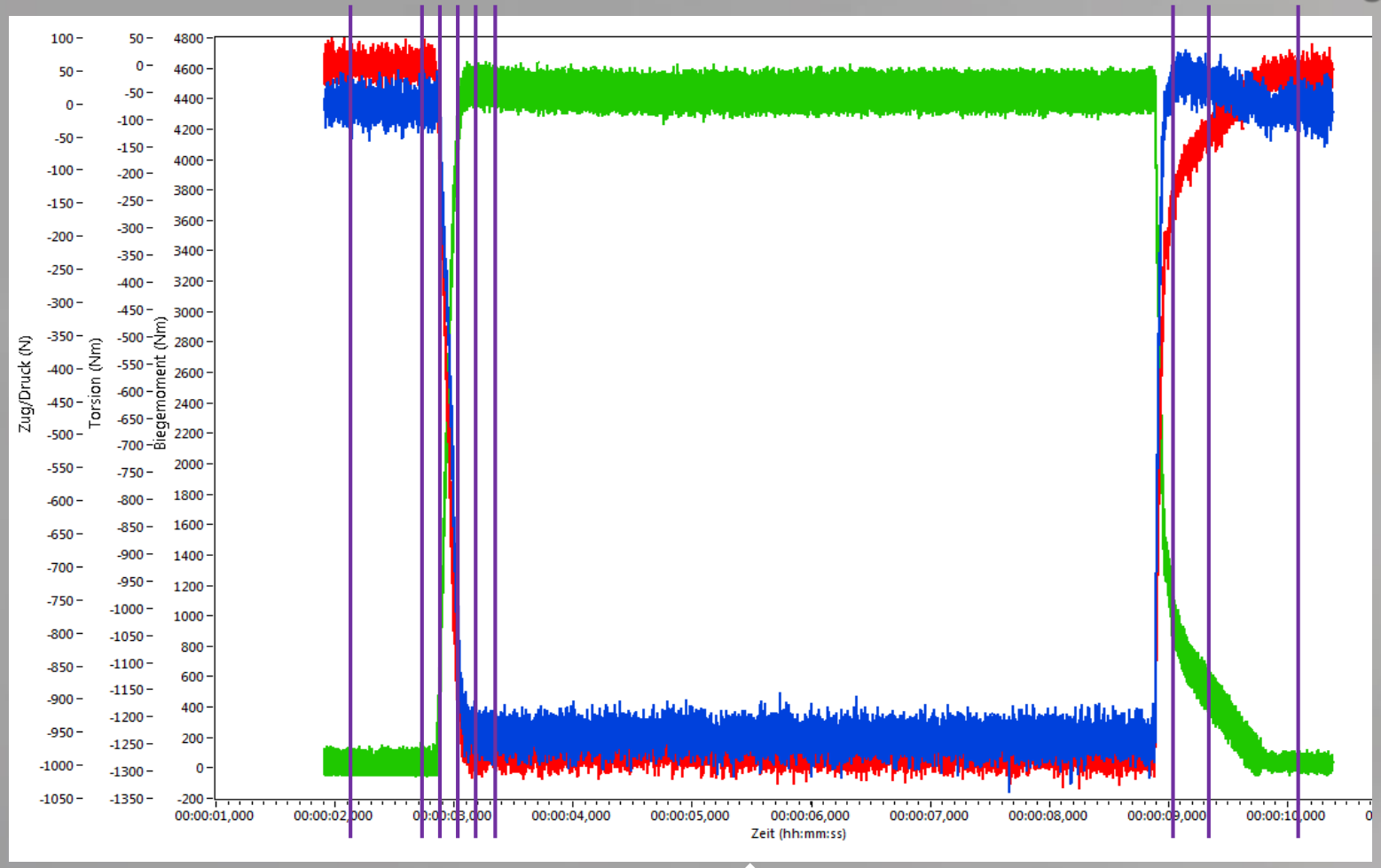
Fmax: **490 N** / **295 N** / **270 N**

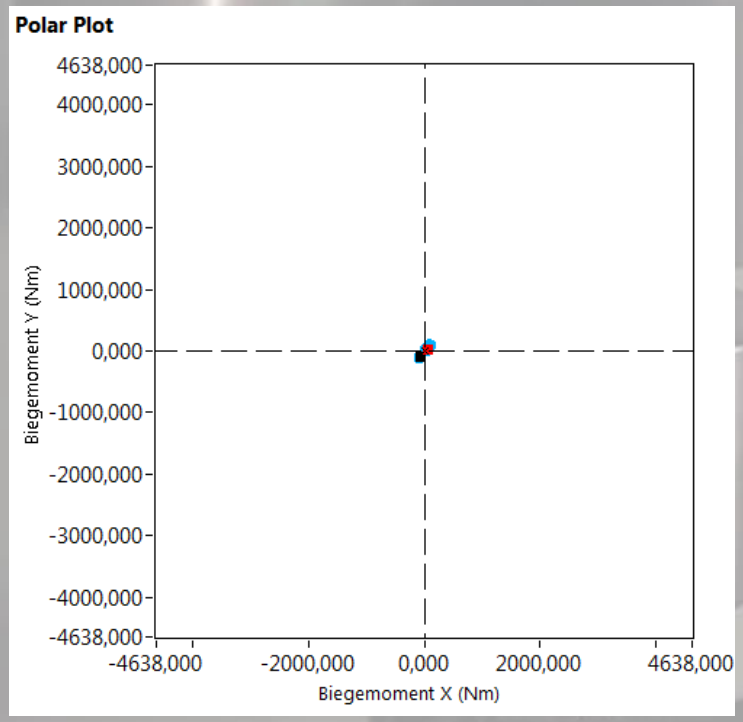


When comparing the tensile compression force, the force at the end of each machining process can be seen when exiting the material. (angle of incidence!)

Turning holder spike® - spike_polar

A "42CrMo4" round steel bar was turned lengthwise at a constant feed rate of, **f = 0.2 mm/U**“. The infeed is also constant (**ap = 3 mm**). The graph shows **tensile/compression (N) – torsion (Nm)** and the **bending moment (Nm)**

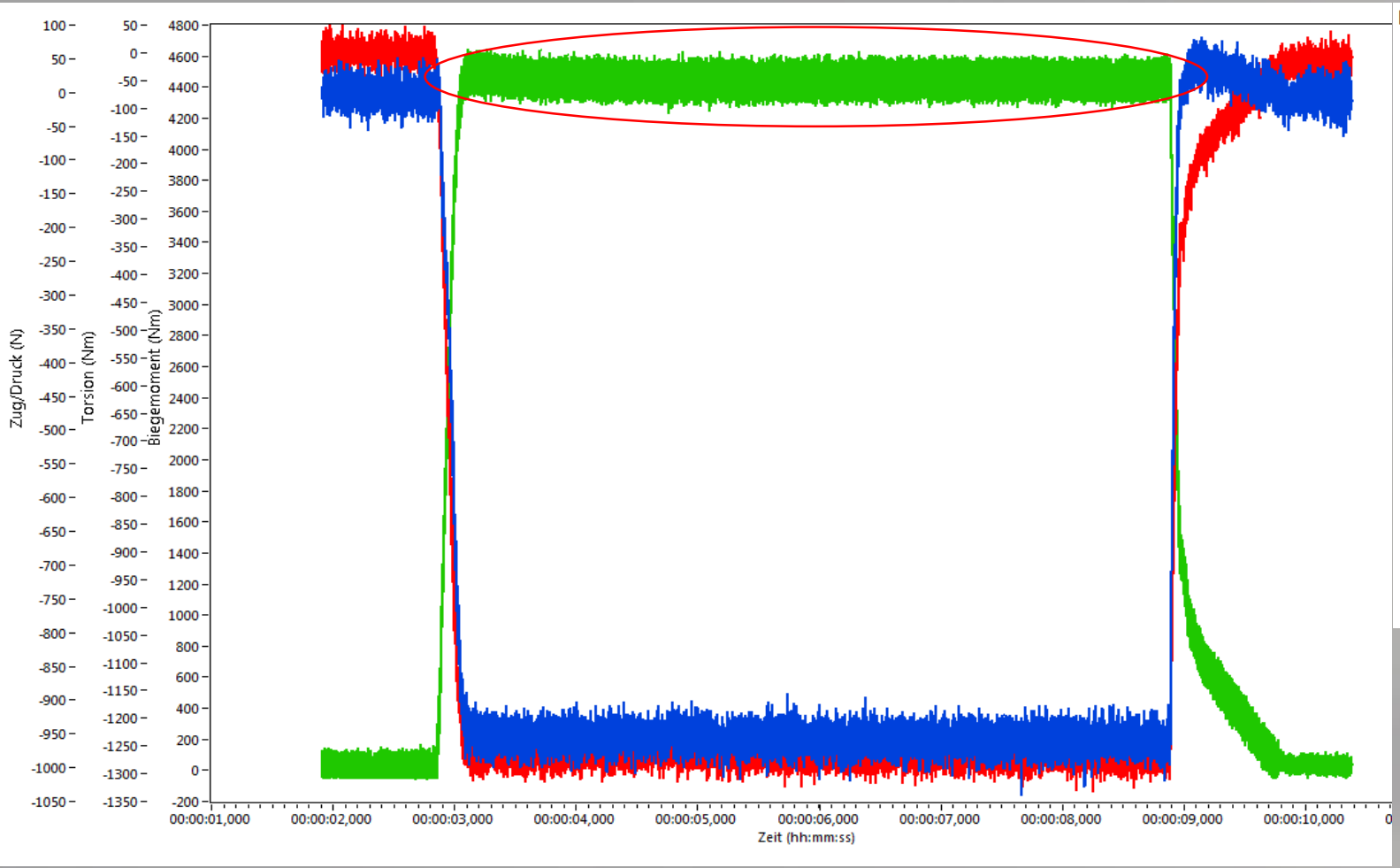


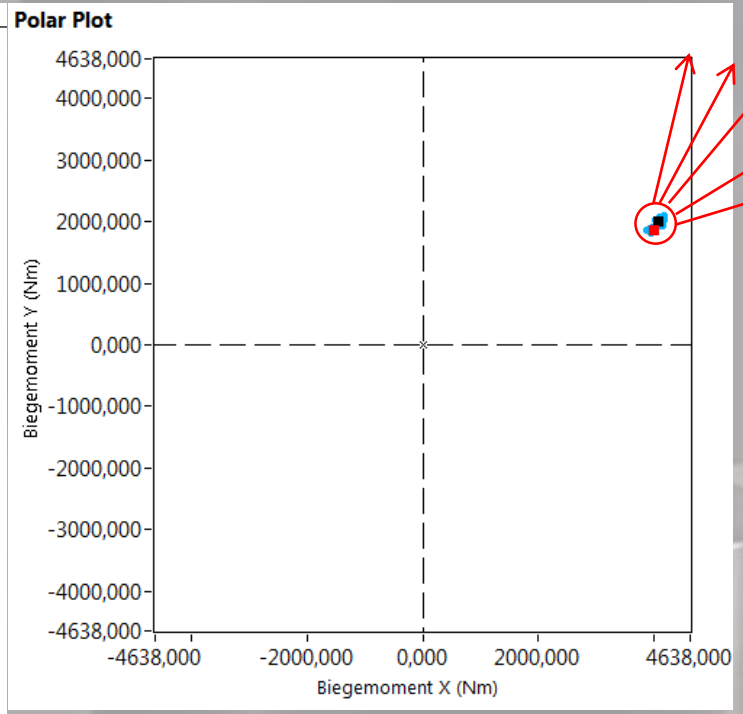


spike®_polar exerpt:
500 points = (0,3 sec)

Turning holder spike® - spike_polar

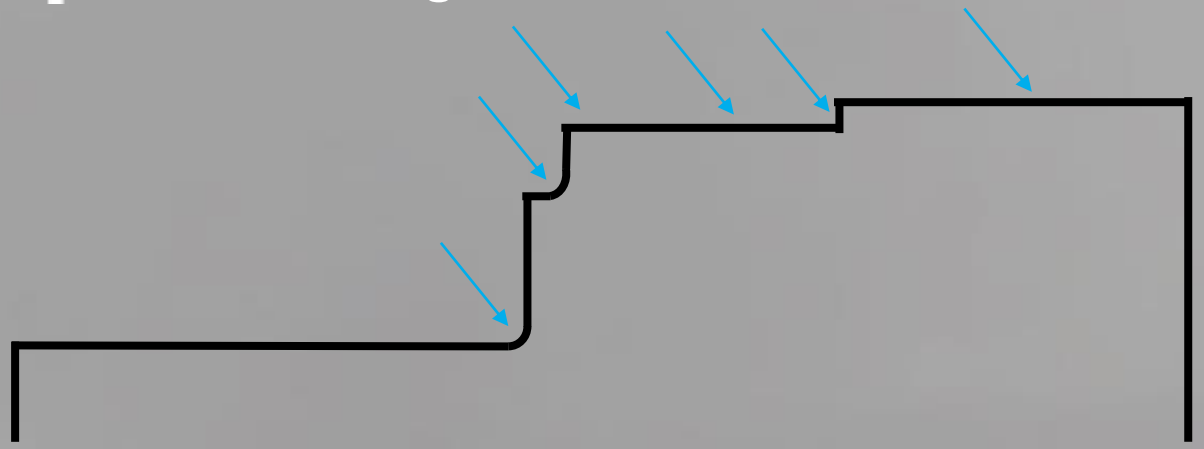
The polar plot can also be used to detect and monitor **cutting edge wear**.

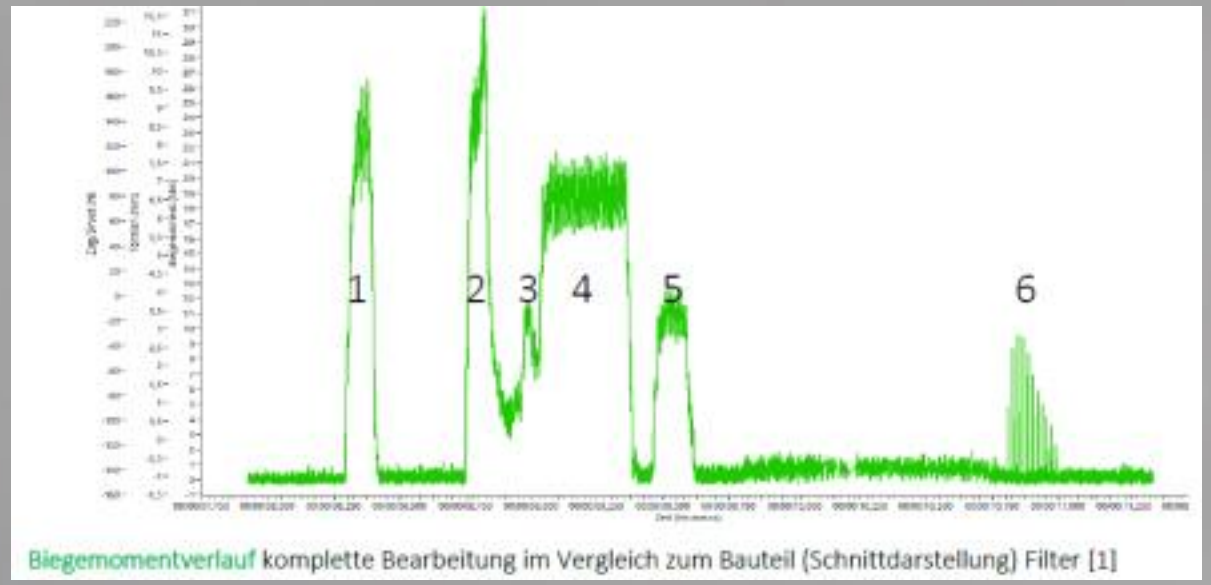




When the cutting edge wears out, the vector of the bending moment moves (with the same cutting data)

spike® Turning – monitor tolerances



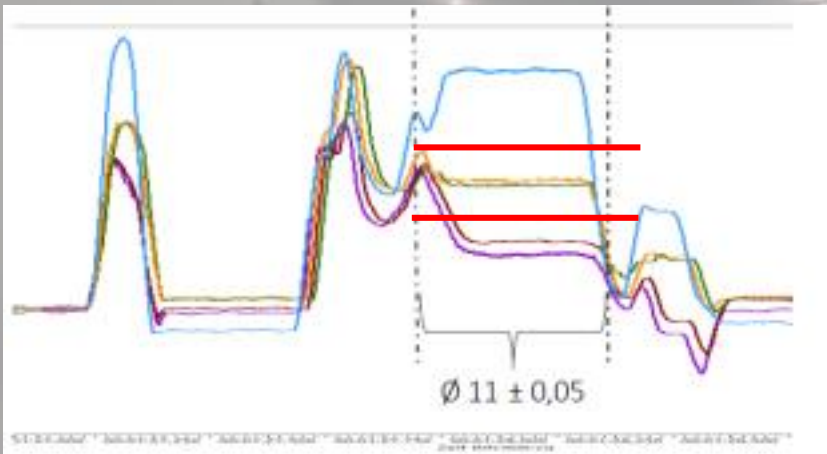


Biegemomentverlauf komplette Bearbeitung im Vergleich zum Bauteil (Schnittdarstellung) Filter [1]

Platte 1 (links) - NEU

Platte 2 (rechts) – Verschlissen

Name	Ist Maß Ø 11 ± 0,05	Sonstiges
Teil 1:	10,5484	Einfahrteil
Teil 2:	11,0021	1. Bauteil nach Radiuskorrektur (Platte 1 - NEU)
Teil 3:	11,0006	2. Bauteil nach Radiuskorrektur (Platte 1 - NEU)
Teil 4:	11,1023	1. Bauteil mit verschlissener Platte (Platte 2 - Verschlissen)
Teil 5:	11,1103	2. Bauteil mit verschlissener Platte (Platte 2 - Verschlissen)



Biegemoment X-Komponente (je kleiner die Kräfte, desto weniger Material wurde abgetragen) Filter [100]

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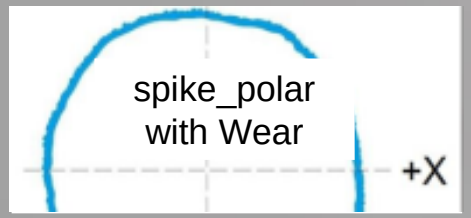
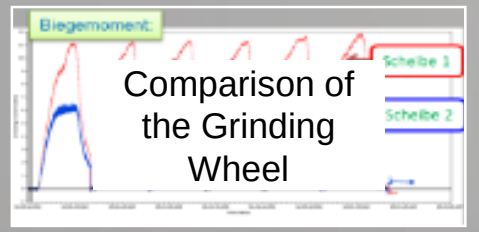
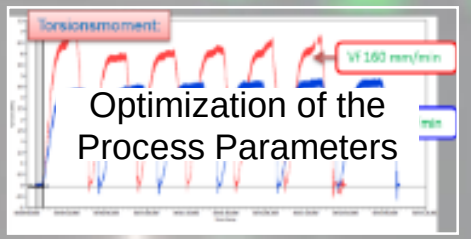
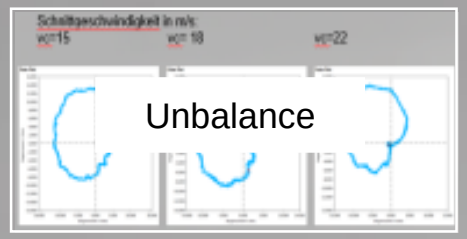
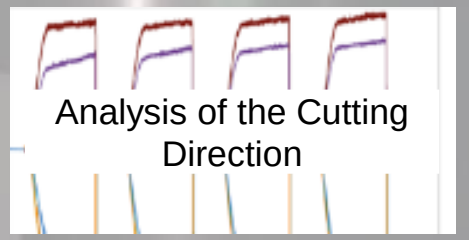
GRINDING

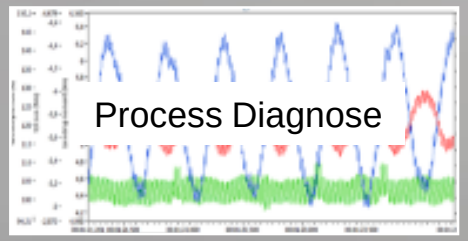




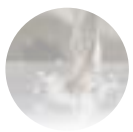
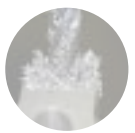




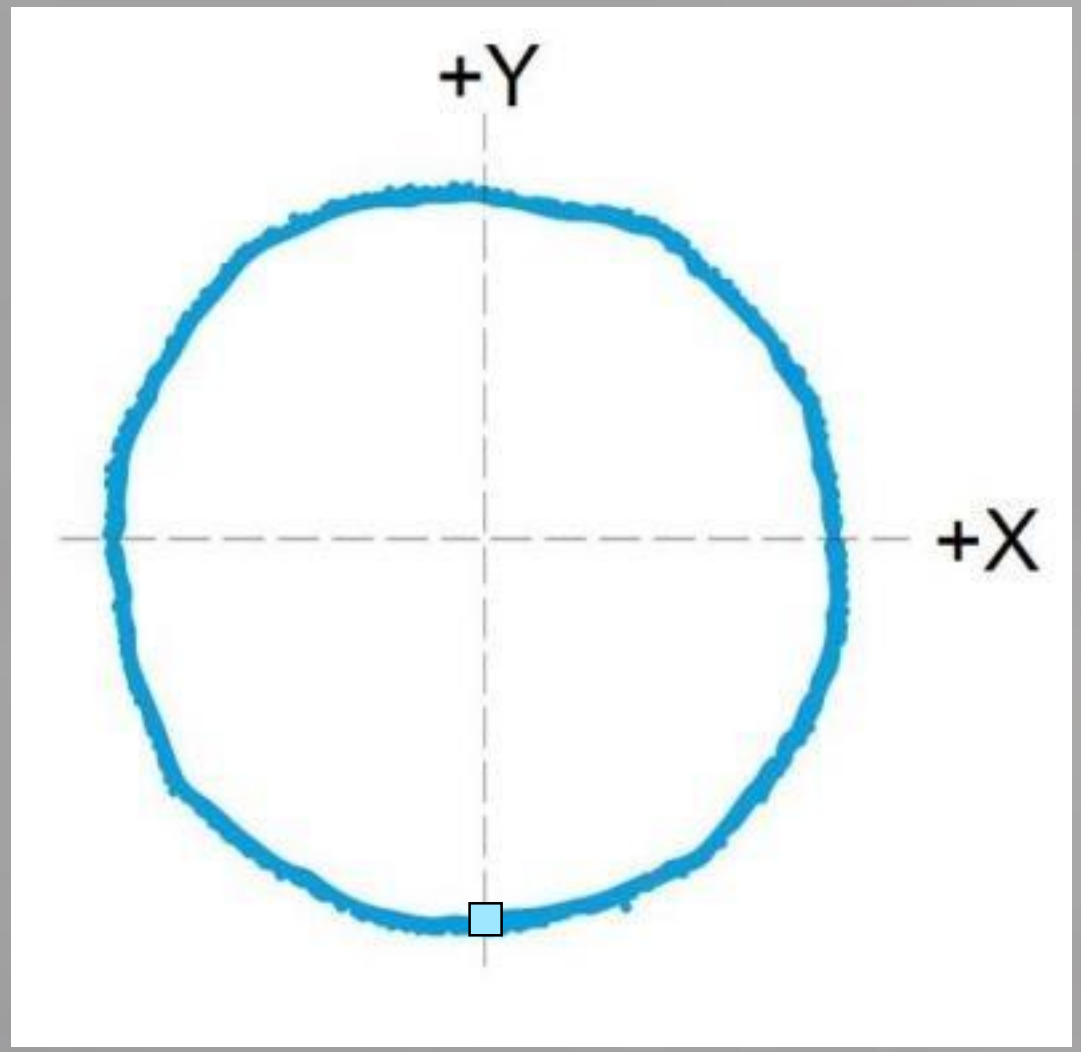


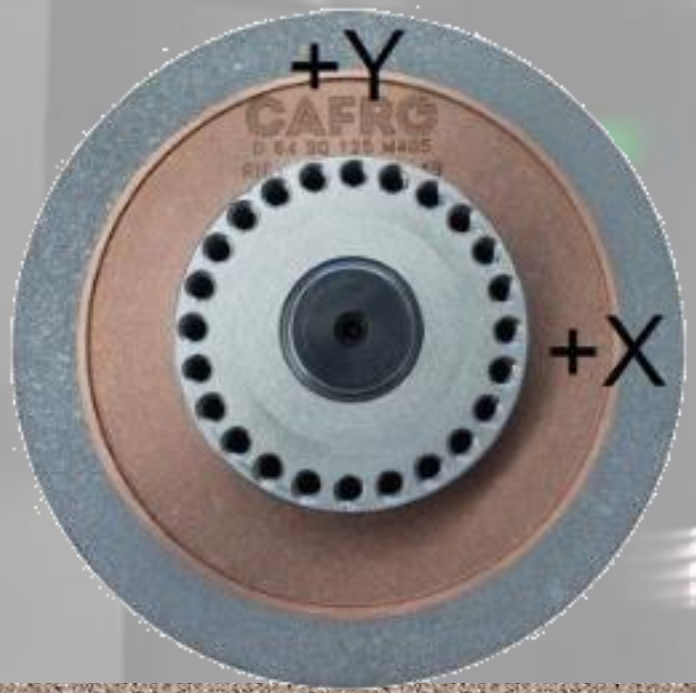




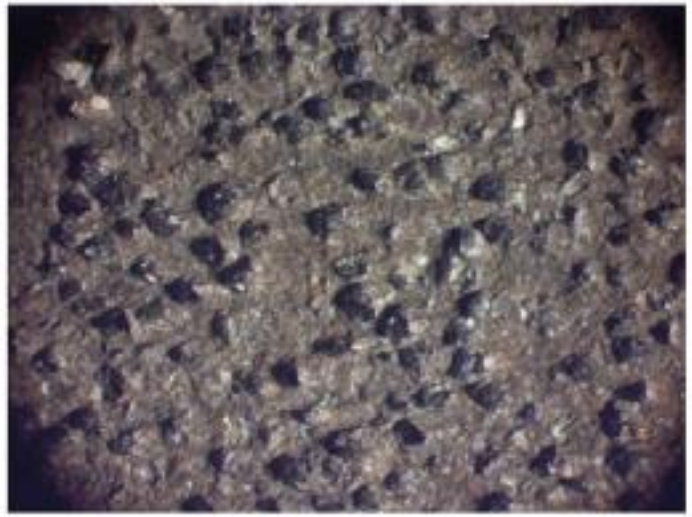



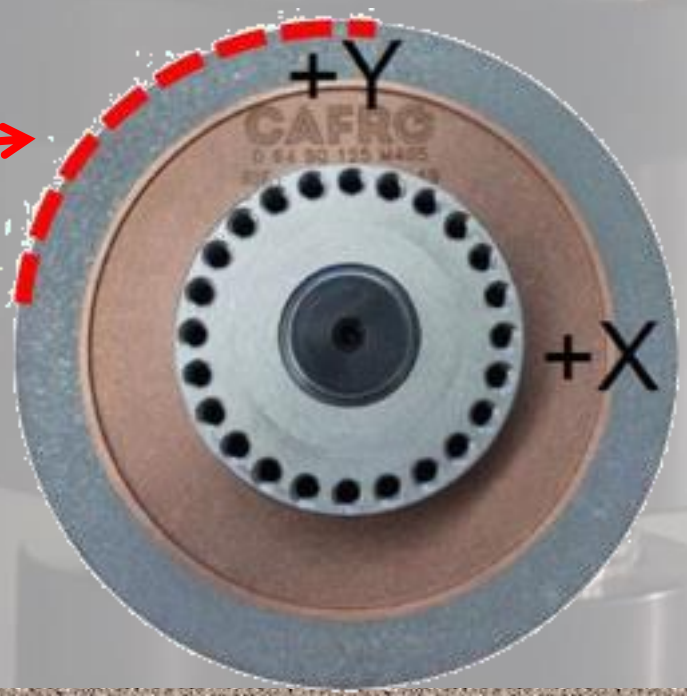

What is the spike_polar?



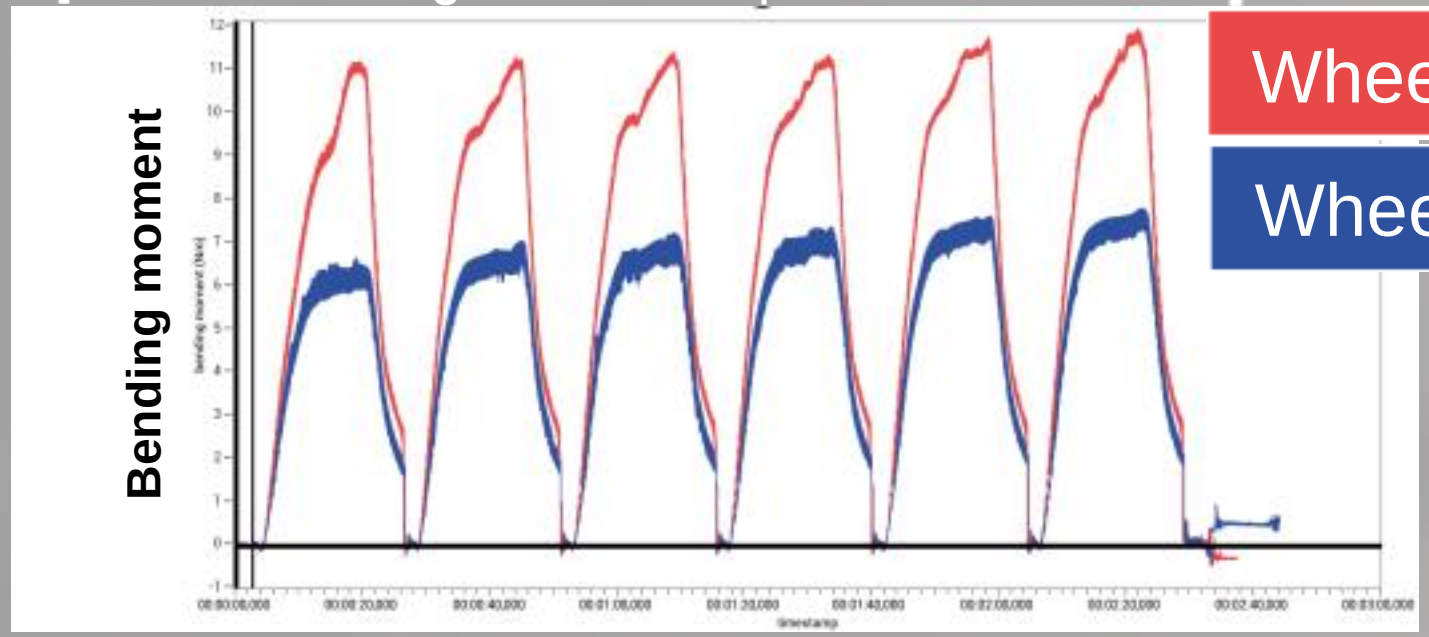


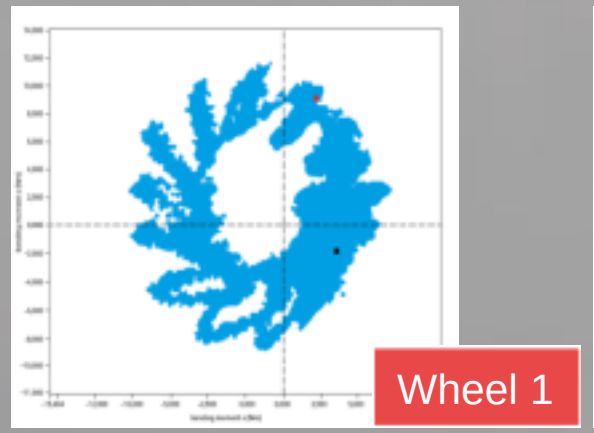
What is the spike_polar?

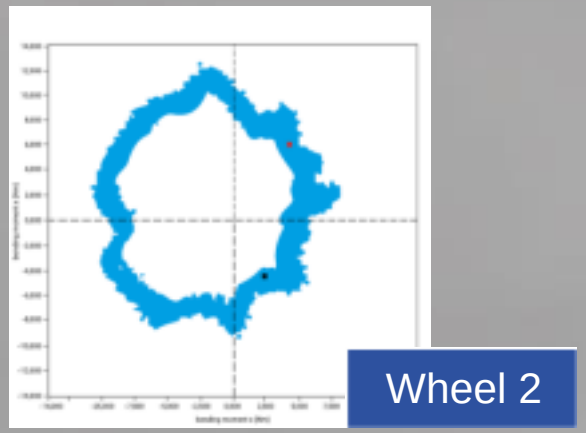




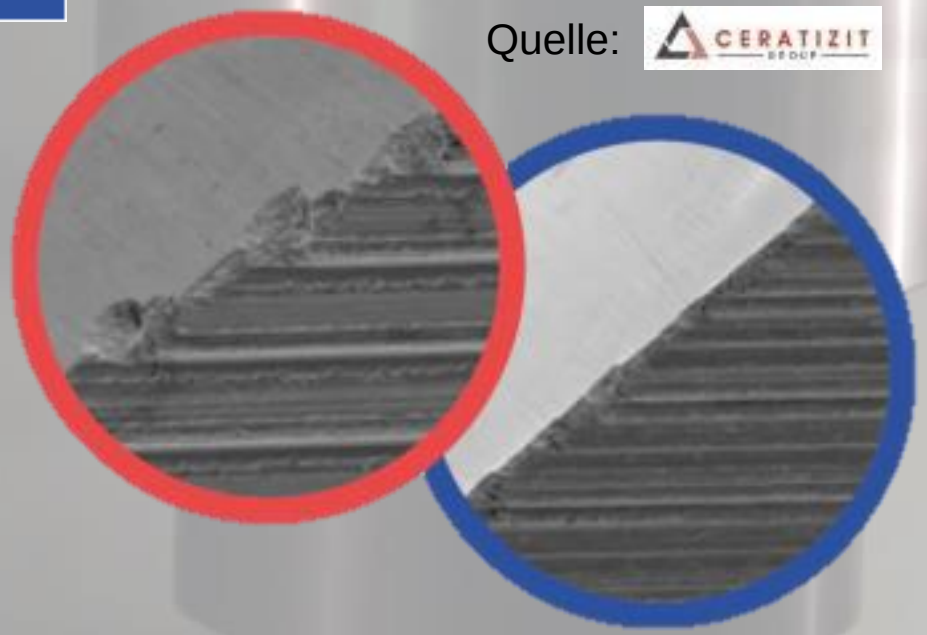
spike® Grinding wheel comparison with the spike®







Quelle: CERATIZIT



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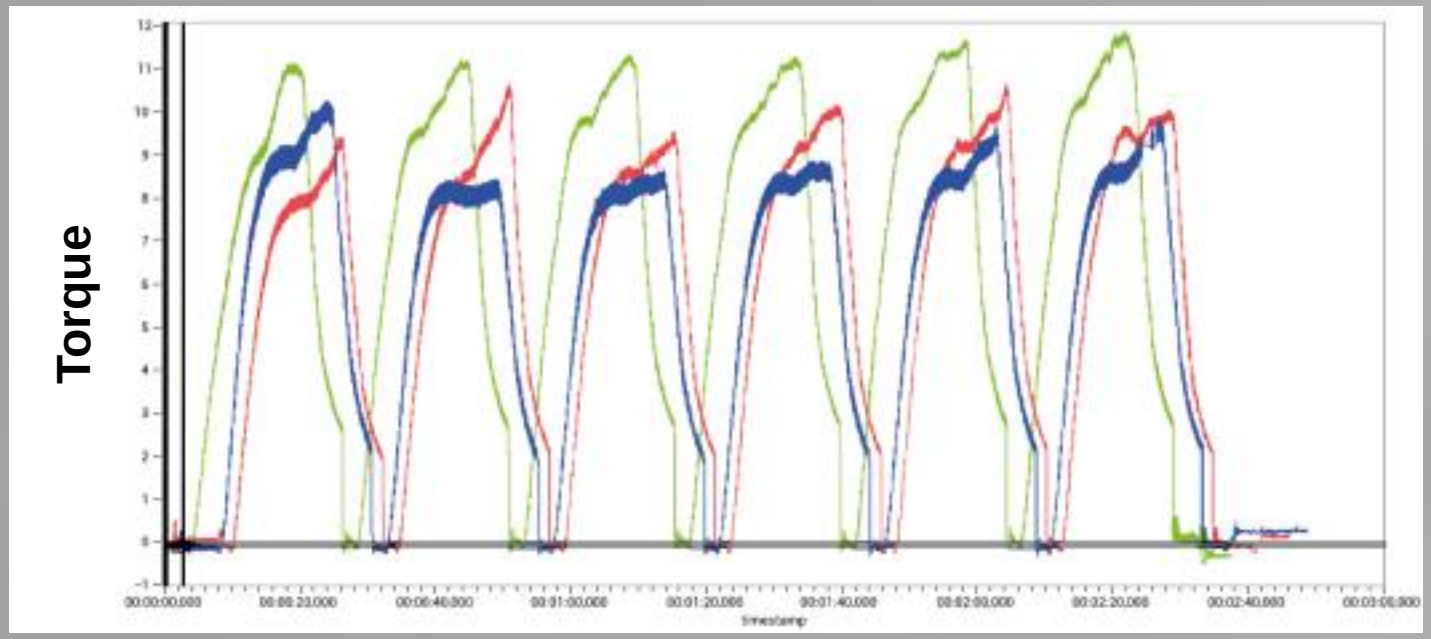
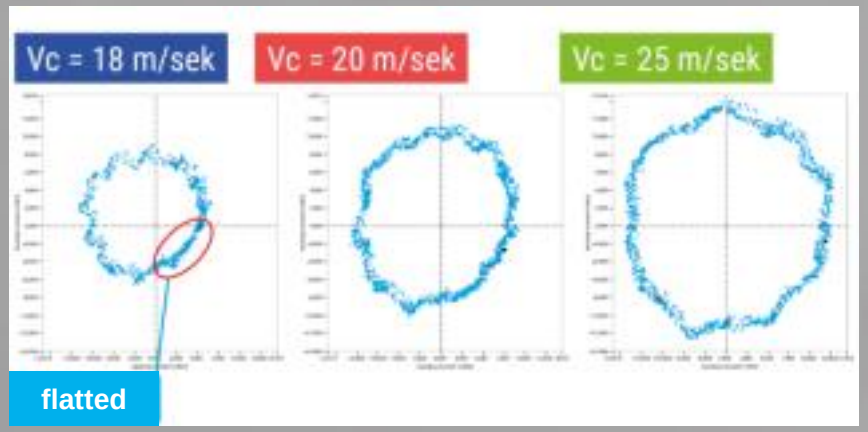
Optimization of the cutting values with spike®





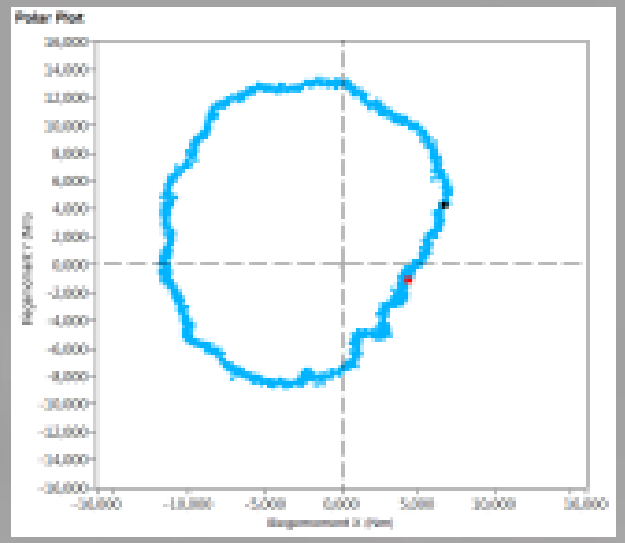
Process stabilization

With the spike_polar, the optimal cutting parameters can be quickly analyzed and determined.
With the spike_polar irregularities in the imbalance or the uniform load of the grinding wheel can be detected.

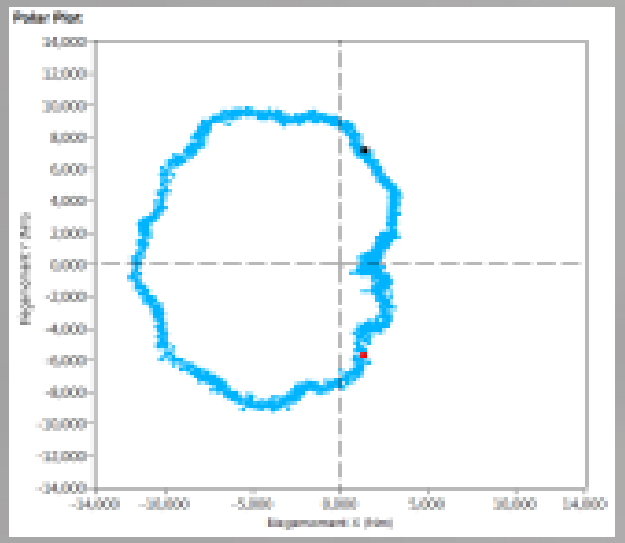
spike® Unbalance - Grinding

Cutting Speed in m/s:

vc=15



vc= 18



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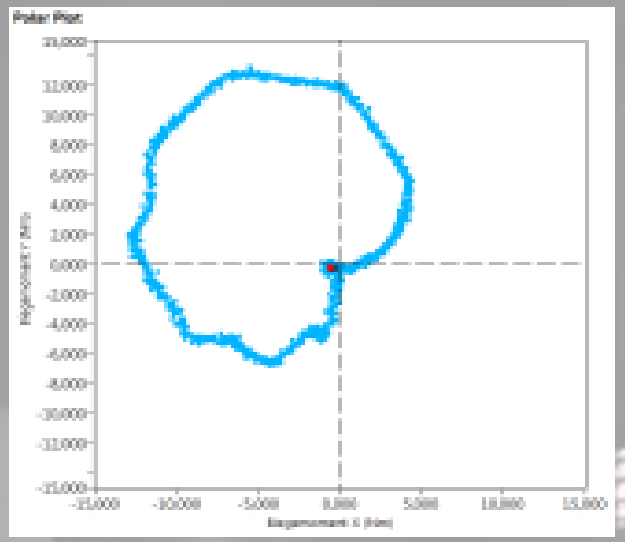


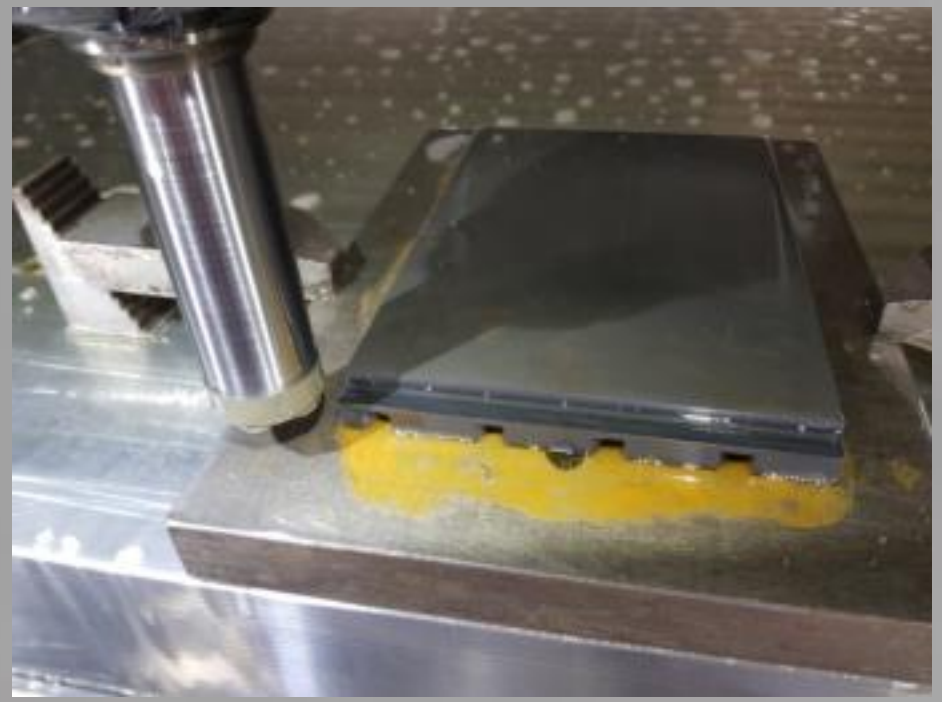
- **Unbalance** in the tool structure leads to **uneven wear of the grinding wheel (see spike_polar)**.

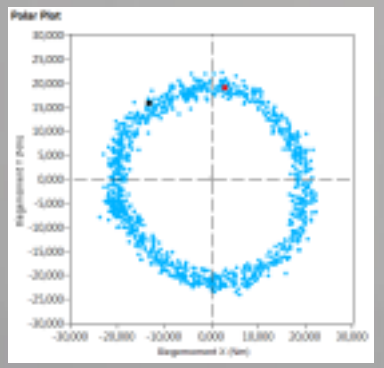
➢ Consequences: **shorter tool life** and **poorer surface quality of the workpieces**

- vc=15 m/s an **unequal load** on the disc, nevertheless **constant contact to the workpiece**
- vc=22m/s, the unbalance ensures that the **bending moment even drops to zero**.
- Result: During each rotation, **the disc does not make contact with the workpiece for a short time**; **the disc hits the workpiece**.

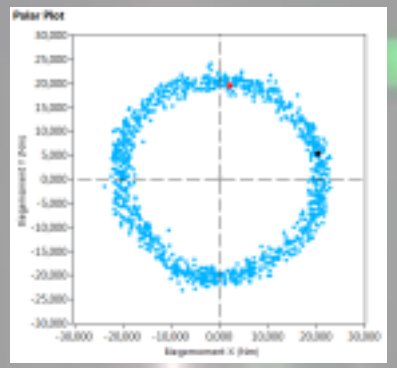
spike® Wear analysis with the spike®

promicron wireless solutions

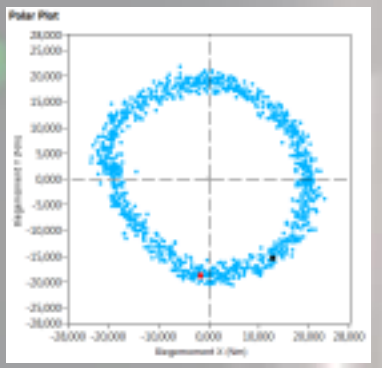




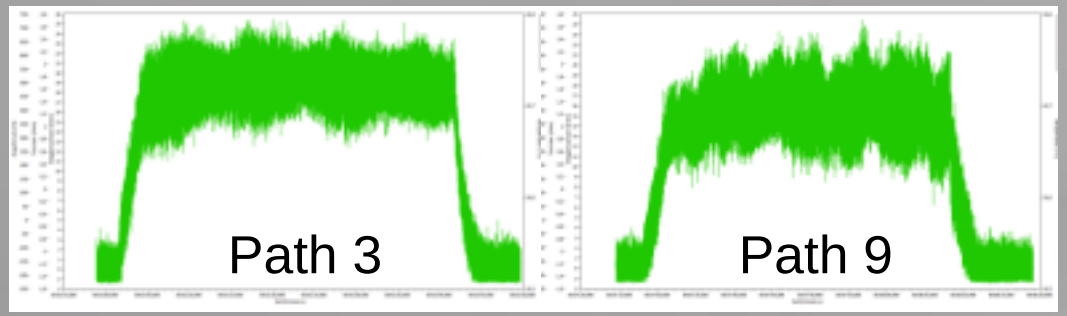
Path 1

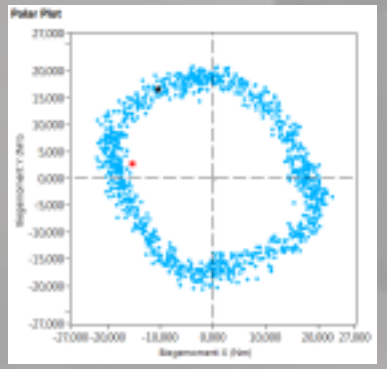


Path 3

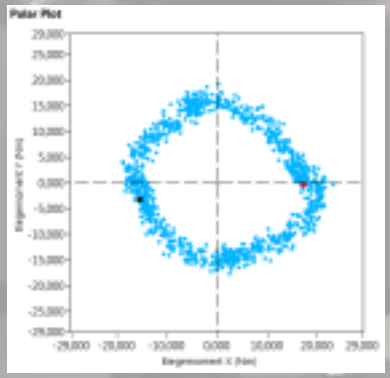


Path 5

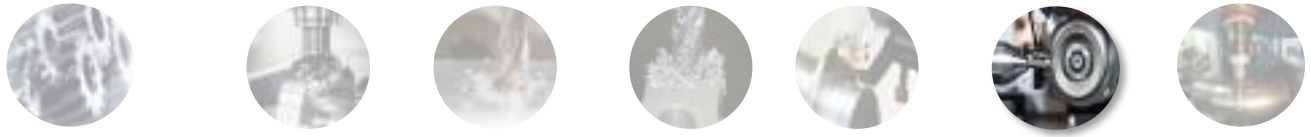




Path 7

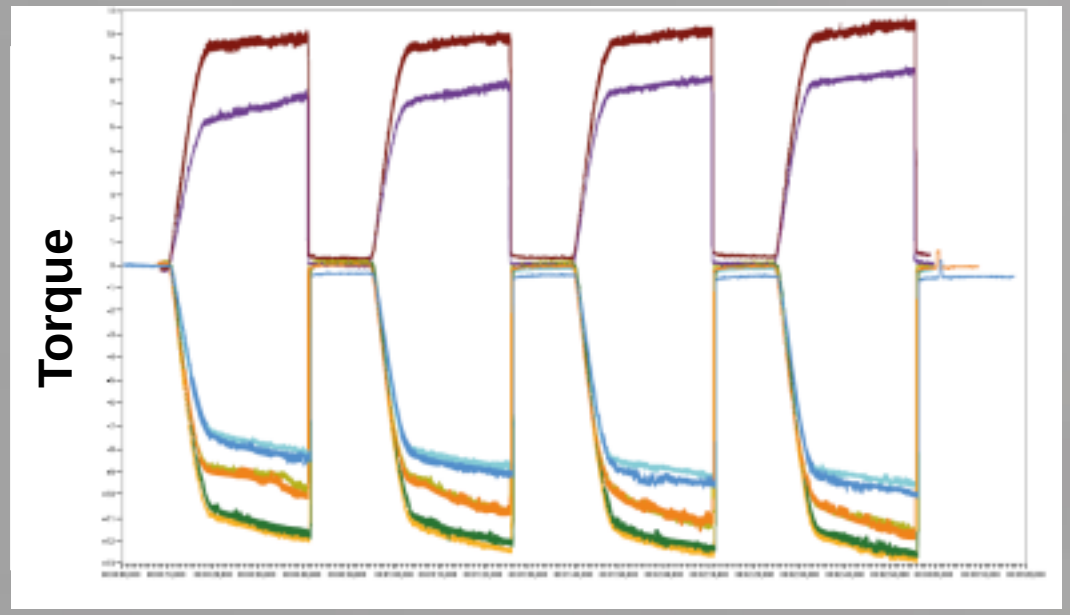


Path 9

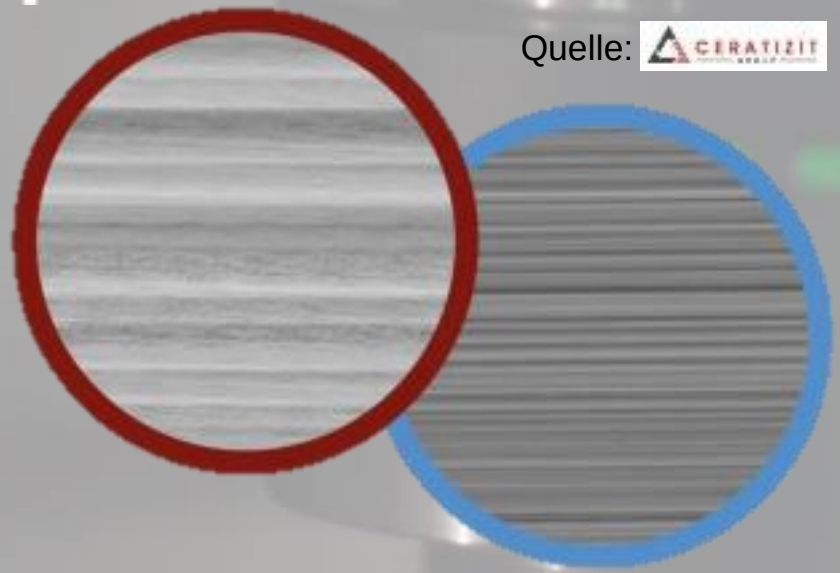


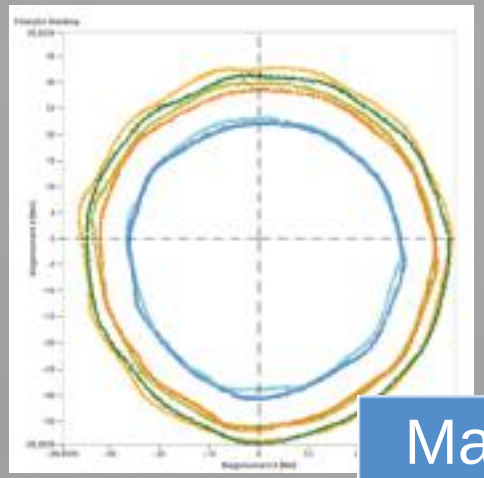
Quelle: H.C.Starck

Analysis of the Cutting Direction with the spike®

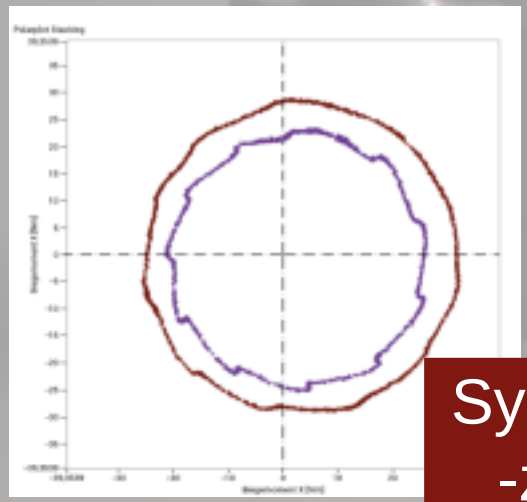


Quelle: CERATIZIT



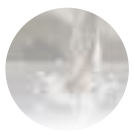
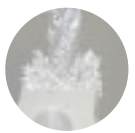


Mating

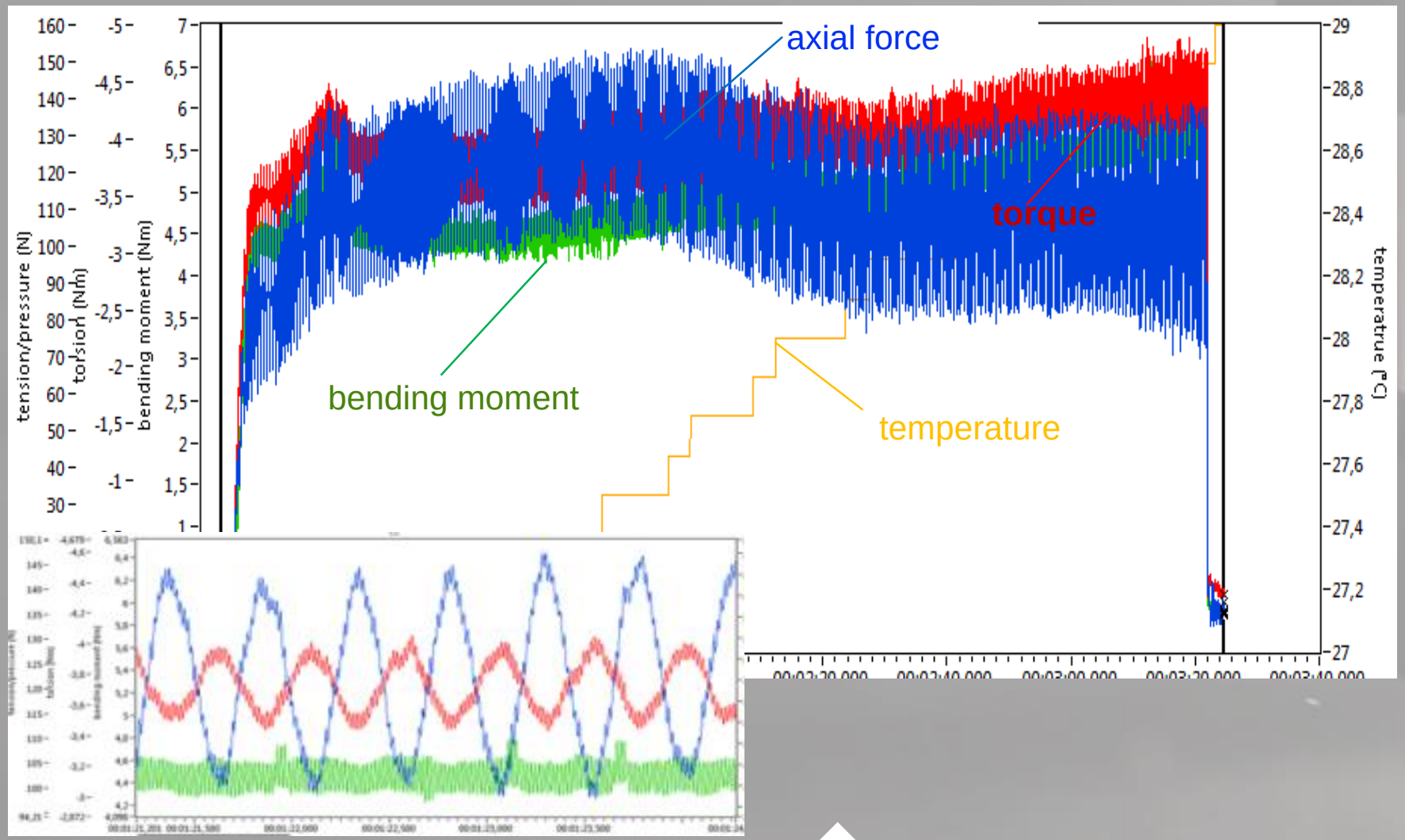


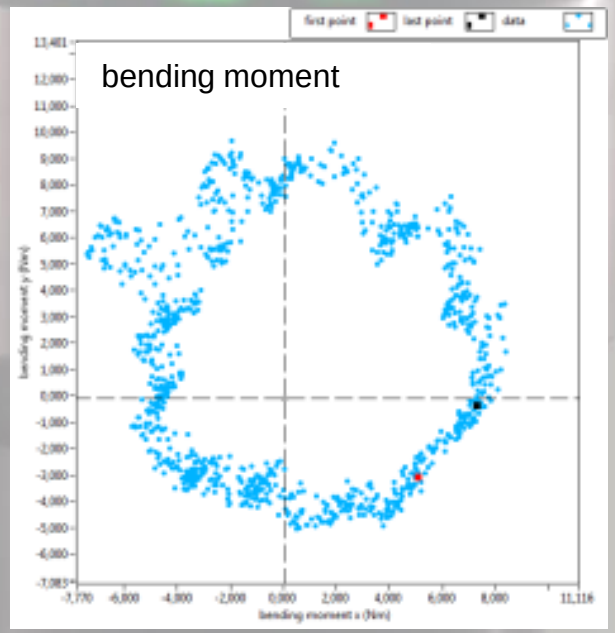
Synchroni
-zation



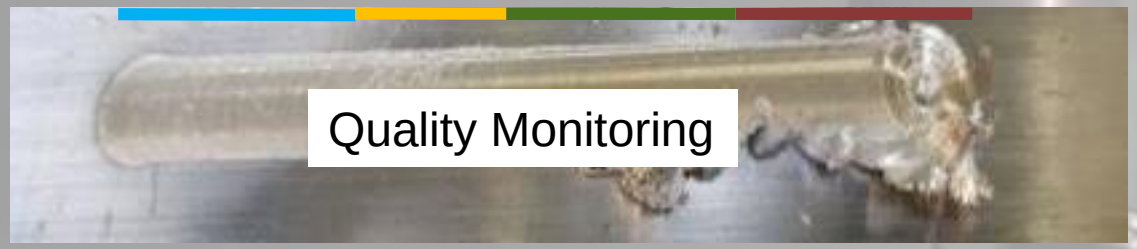

Process Diagnosis – Grinding of a Deep Hole Drill



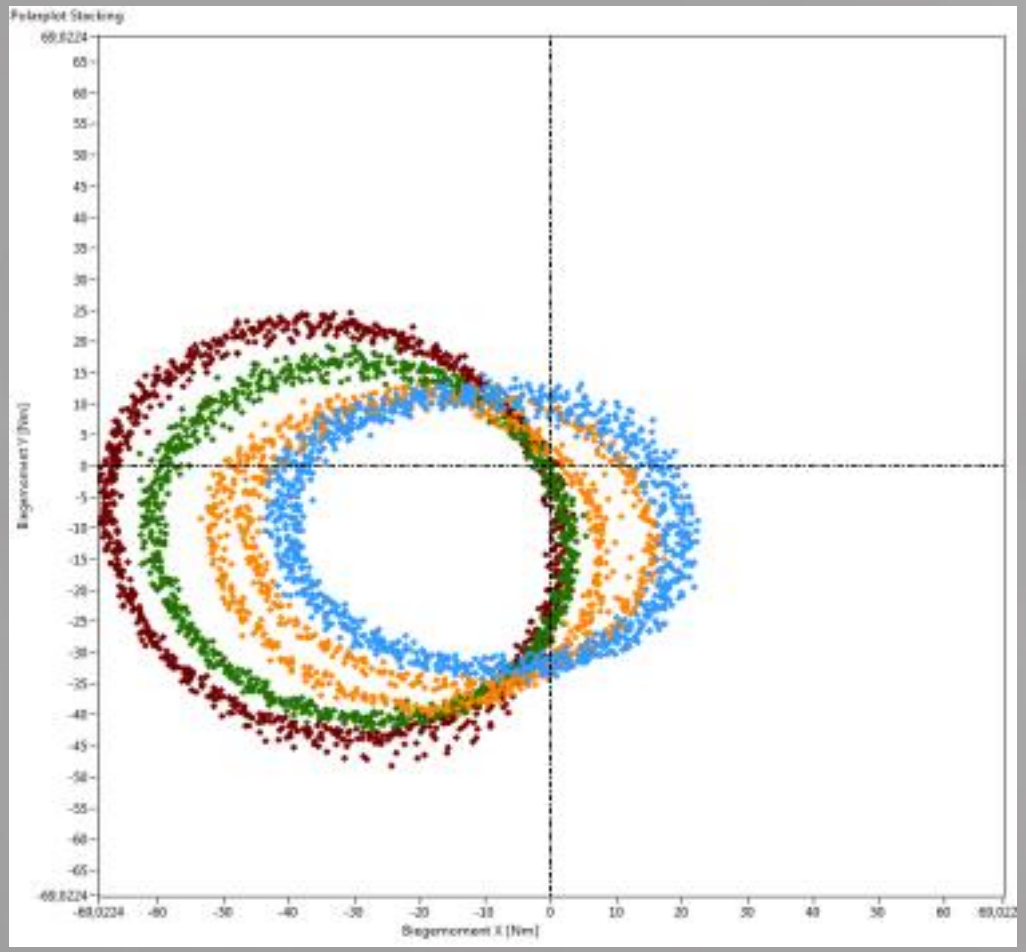


Friction Stir Welding

FSW



FSW – Quality monitoring



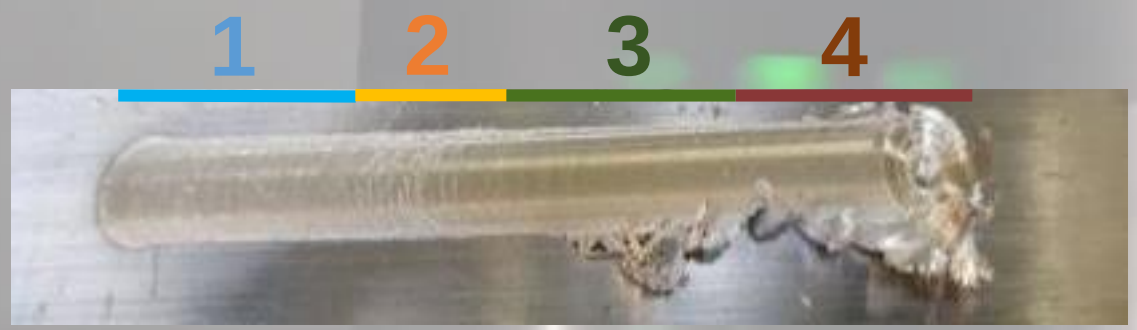
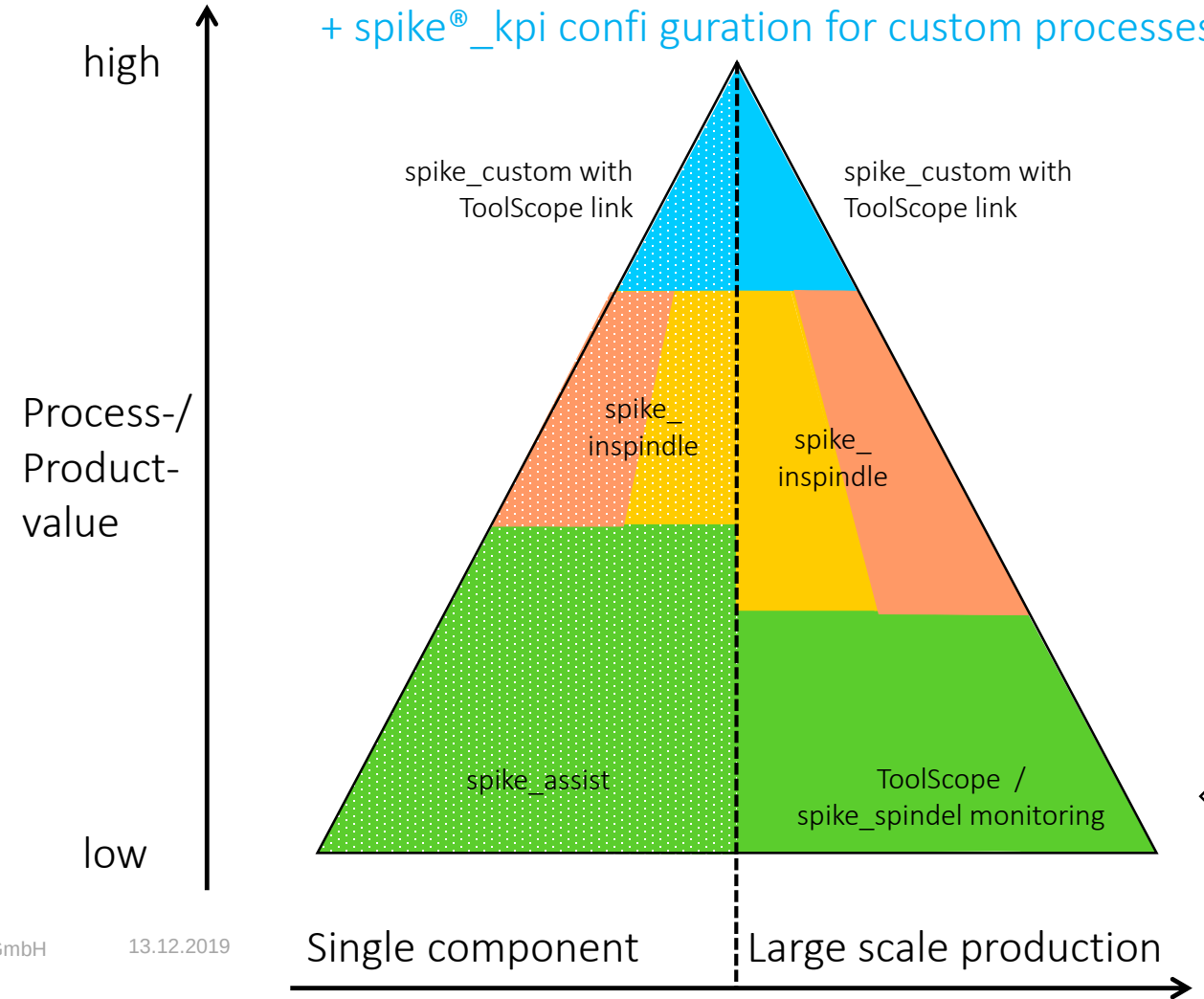


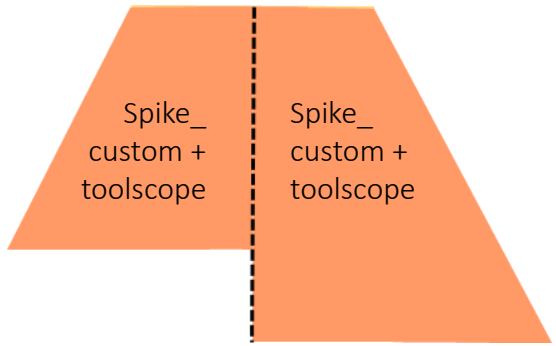
Figure 10: spike_polar stacking shows the curve of the bending moment

potential-oriented market segmentation for monitoring solutions in machining

+ spike®_app as a mobile event reporting device
+ spike®_ai as automatic interpretation aid
+ spike®_expertline for processdiagnose
+ spike®_dataservices for process neutral and specific applications
+ spike®_kpi confi guration for custom processes

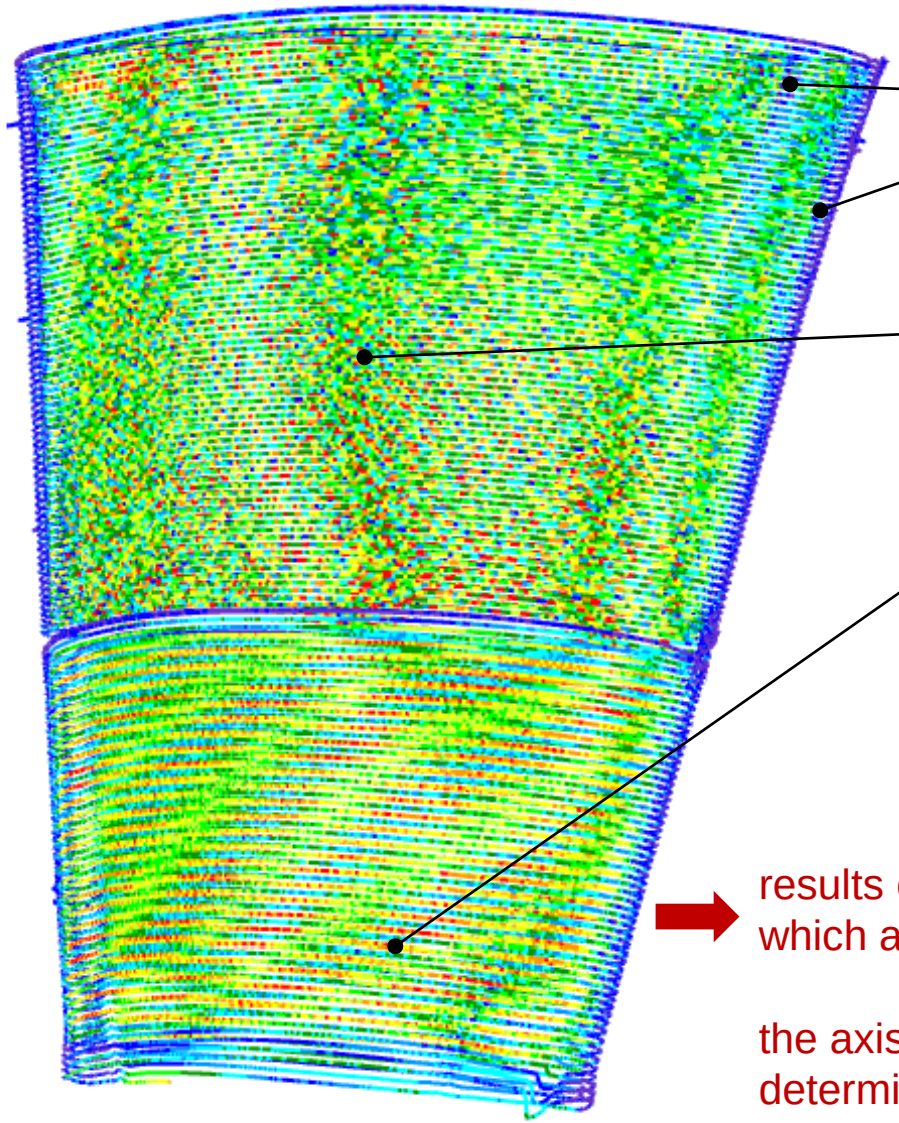


alternative:
spike_custom with
ToolScope link



⇐ Machining market

spike® data linked to component geometry



breakdown of cutting forces/ bending moments

almost constant cutting force

low frequency fluctuation of cutting force.

Validation of the spike sensory tool holder through the:

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

results of bending moment forces,
which are shown on the digital twin of the component.

the axis coordinates of the machine tool are used to determine the unique position.

spike®

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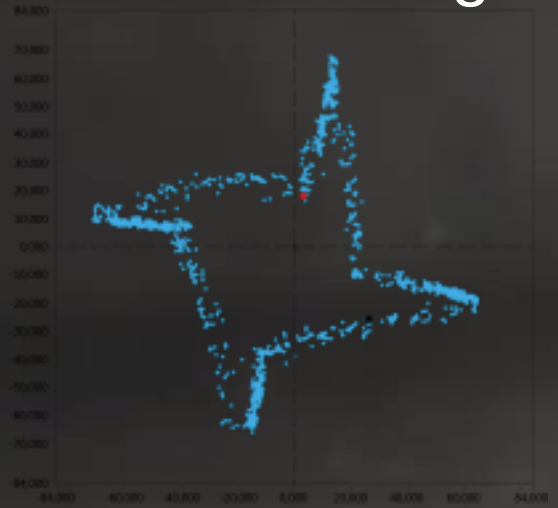
wireless solutions

spike®

CONTROL THE FORCE

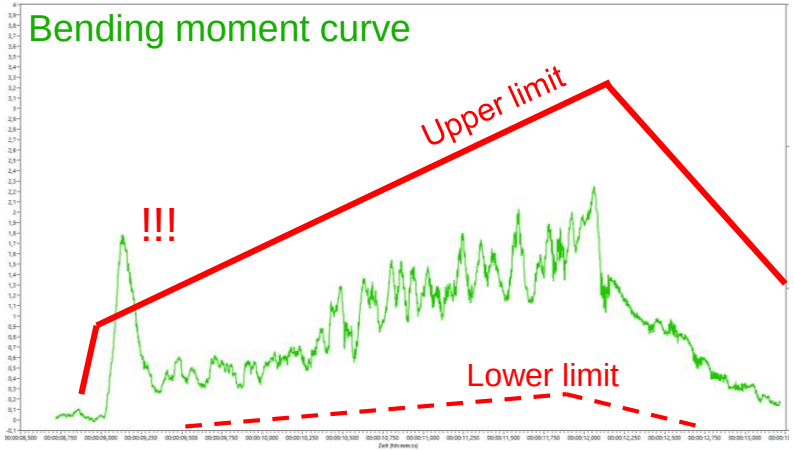
Studie spike®_ai:
Automated detection of drilling errors by machine learning



Differentiation of process monitoring strategies

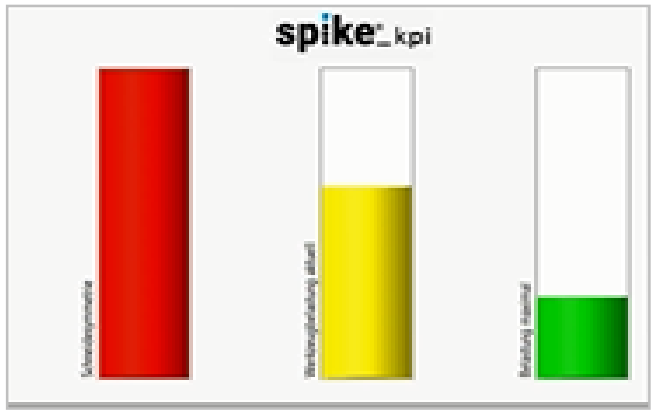
promicron wireless solutions

Envelope curve monitoring



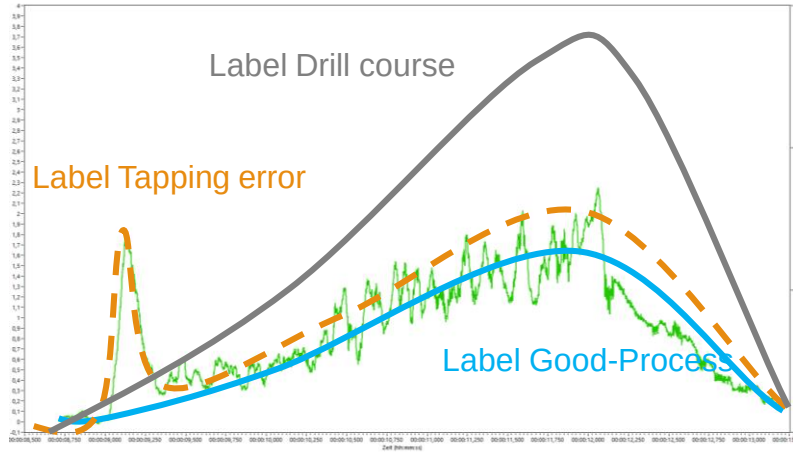
- No error differentiation
- Mostly static limit values
- Definition of limits values is elementary

spike®_kpi



- Data preprocessing
- spike®_kpi describes disturbance quantity in type and strength
- Process-specific spike®_kpi preselection
- Tool-specific spike®_kpi limits

spike®_ai



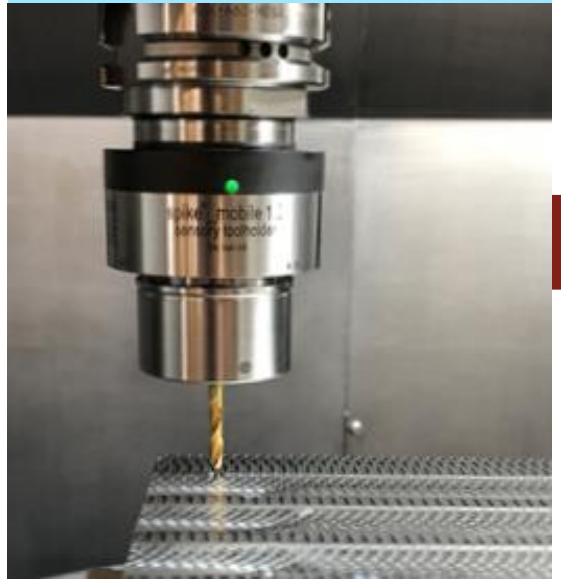
- Signal patterns are searched and found → Conclusion on type of fault
- Different error classes/labels can be learned → Expandability and adaptability
- Transfer of error characteristics to the initial level
- Prediction accuracy increases with the amount of learned data
- Added value through external data integration

Automated detection of drilling errors by machine learning

promicron wireless solutions

Application of the supervised learning methodology to detect production interruptions during drilling

Measurement

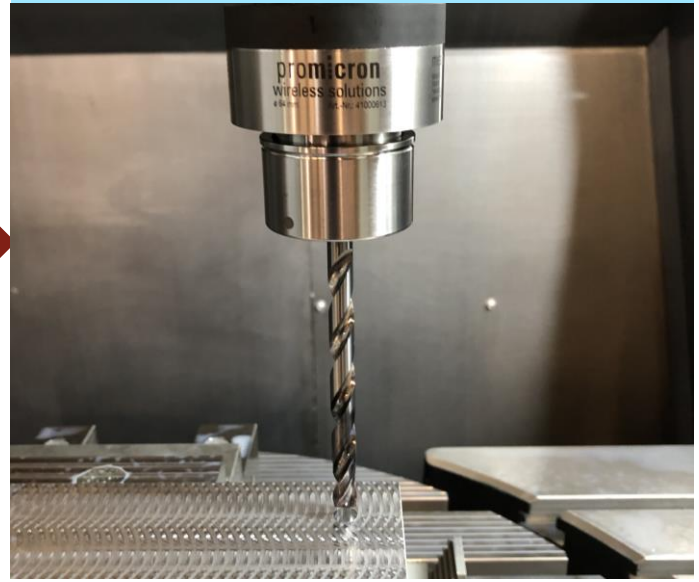


- 100 measurements for ai system training
- Recording of process loads per spike_mobile
- Drill hole: Ø4.2 mm, 4xØ deep
- coated short hole drill
- workpiece material 1.0122

Training spike®_ai system

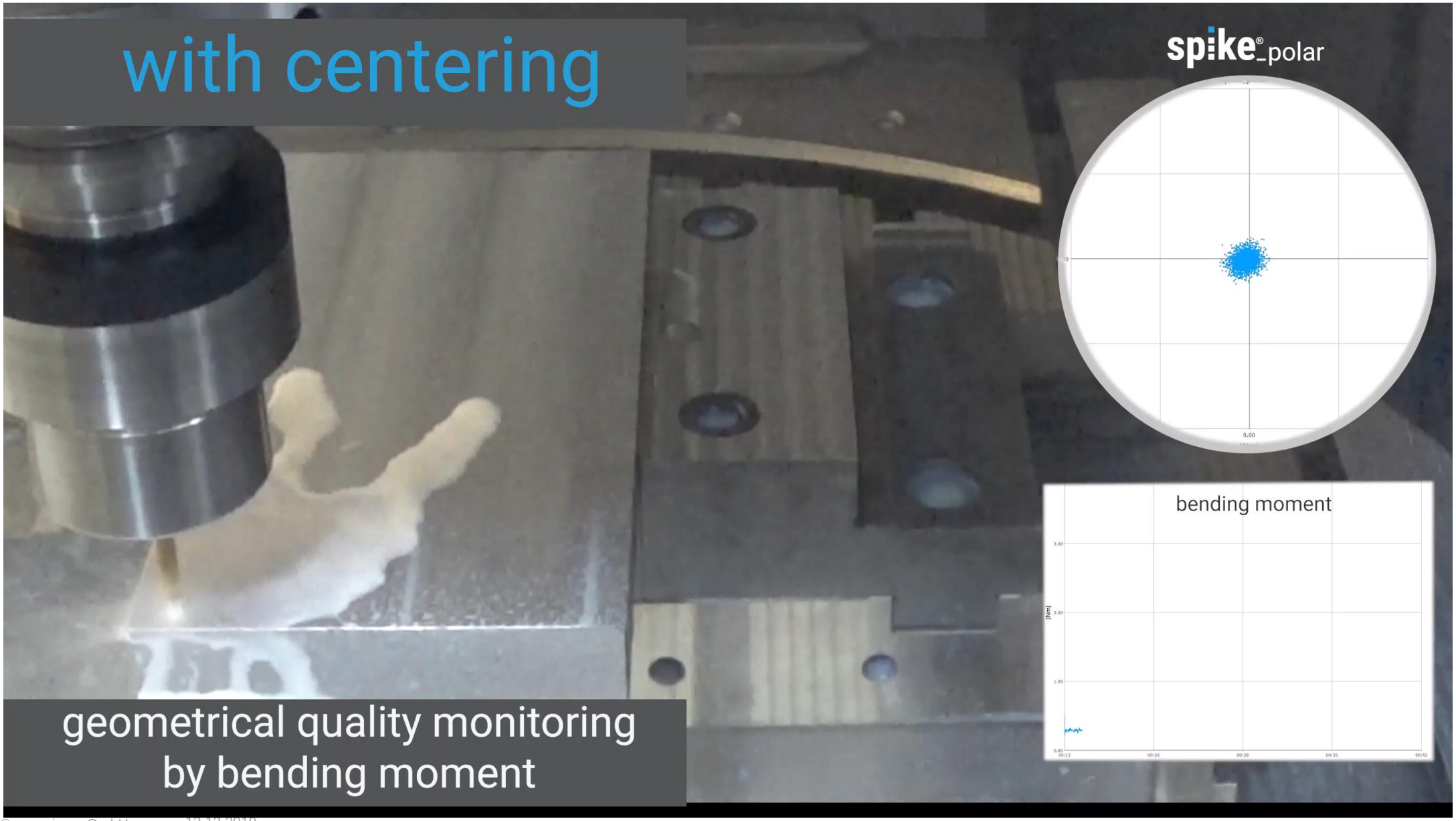
- Classification of drilling errors using labels
- neural network (LSTM) maps process load curves on labels
- Software in Python, based on PyTorch

Verification & Generalization



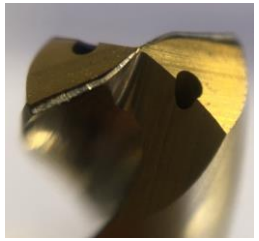
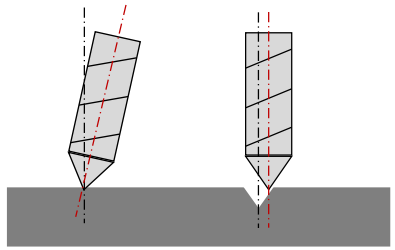
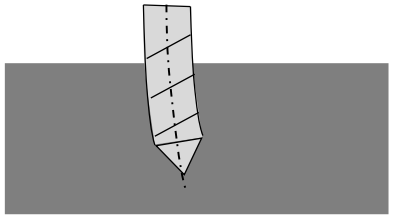
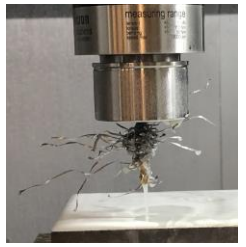
- Test with the same drill type for verification
- Test with modified process (Ø8.5mm deep hole) to check generalizability
- Determination of detection accuracy

Example – Detection with centering



Error detection with 100 trained holes

promicron
wireless solutions

No disturbance	Label Tool wear	Label Tapping error	Label Drill course	Label Chip clamp	Label KSS-Disturbance
Quality ✓ Tool load ✓ Stability ✓					
Good process	Disturbed process in general				

Determination with an accuracy of 95% after 100 trainings

Good process	Disturbance Tool wear	Disturbance Tapping	Disturbance Drill course	Disturbance Chip removal	Disturbance KSS

Differentiation specific disturbance with an accuracy of 69%.

promicron wireless solutions

Product:

Quantity p.a.:	6.000.000 Pieces
Quantity p.m.:	500.000 Pieces
Machines total:	90 Pieces

- Breakage of the old tool every 300 pieces — costs per tool 30,00 EUR
- New tool — costs per tool 80,00 EUR
- Change of cutting insert every 3.000 pieces — per cutting insert 30,00 EUR

Savings on tooling costs

- Tooling costs can be reduced by **73 %**

Tool costs old tool per machine p.a.	6.666,67 EUR
Tool costs for new tool per machine p.a.	746,67 EUR
Savings per machine p.a.	5.920,00 EUR

Savings for 90 machines p.a. **532.800 EUR**

→ Consideration of tool costs only

Old tool
Life time 300 Stck.
Tool costs 30,00 EUR

New tool
Life time 3.000 Stck.
Tool costs 80,00 EUR
Replacement cutting insert 30,00 EUR

spike® Reduction of machine downtimes due to tool changes

promicron wireless solutions

Current (old tool):
- Tool change after 300 pcs.
- Standstill time for tool change 18.52 hours p.a.

Optimization (new tool):
- Tool change after 3,000 pcs.
- Downtime for tool change 1.85 hours p.a.
- By increasing the tool life by 1000%, machine downtimes can be reduced to 10%.

current downtime costs p.m.p.a.	1.388,89 EUR
optimized downtime costs p.m. p.a.	138,89 EUR
Savings p.m.p.a.	1.250,00 EUR
Savings for 90 machines p.a.	**112.500 EUR**

→ Only the reduction of machine downtimes is considered

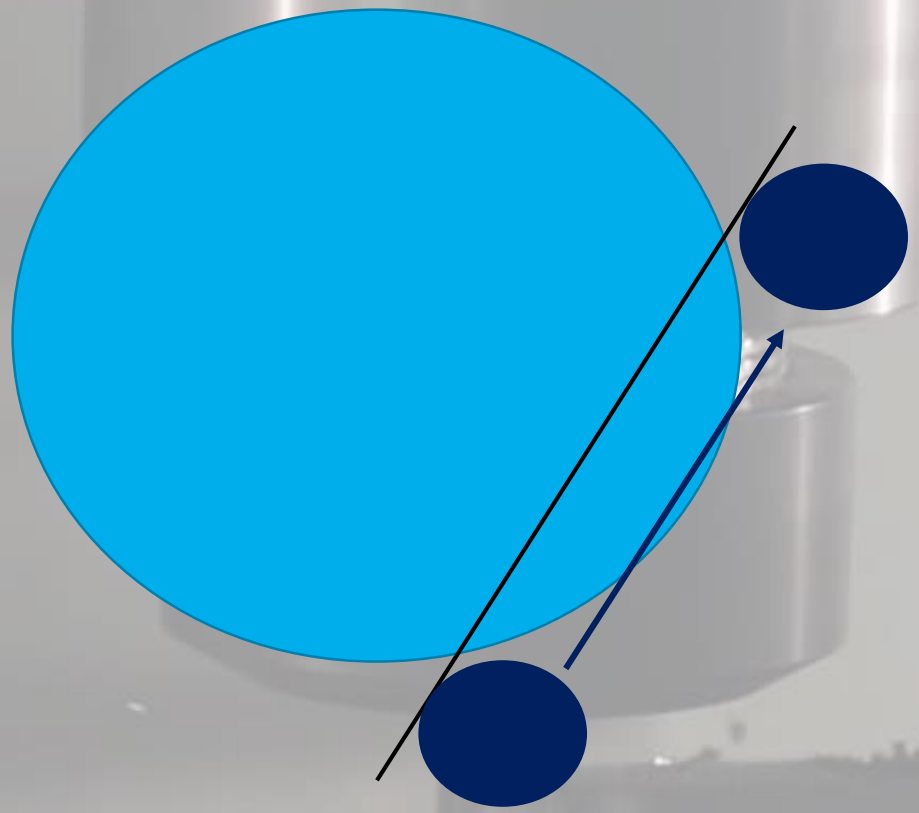
Tool change time 5 min
Machine hour rate 75 EUR/hr.
Machines 90 pcs.
Number of pieces p.a. 6.000.000 pcs.
Number of pieces p.m. 66,667 pcs.

Calculation downtime p.a.:
Quantity p.M.p.a. / tool life = number of changes
Number of changes x duration of change = standstill time

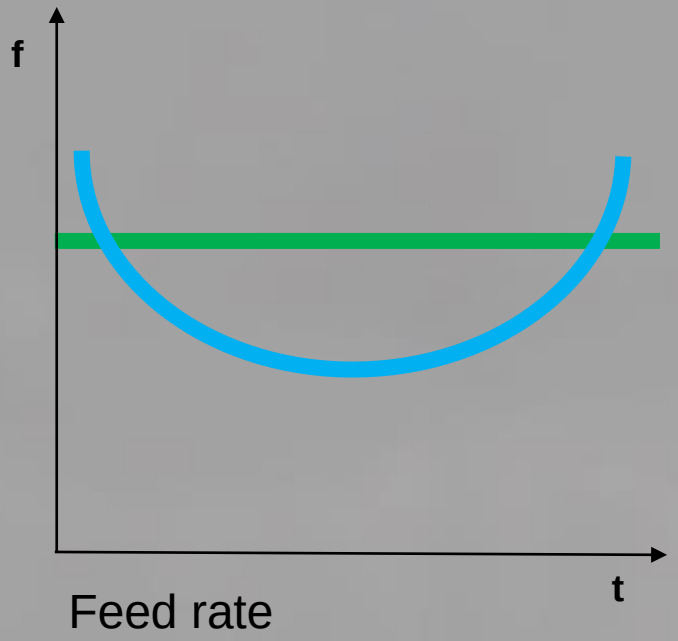
Savings due to adaptive feed control (e.g. key surface)

- Milling of the key surfaces with constant feed speed

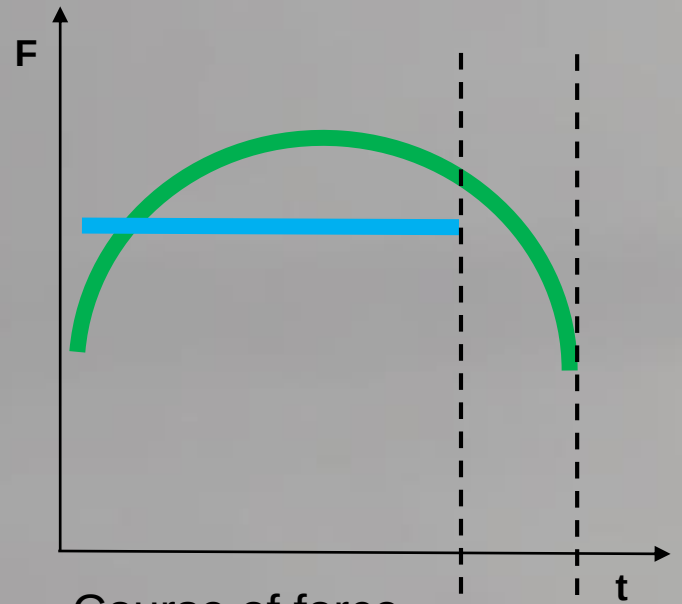
Workpieces per hour p.m.	12,63 pcs./hour
Machine hour rate	75 EUR/h.
Tool wear	3,000 pcs.
Tool change time in case of wear	5 min



Machining of key surfaces - Comparison of feed rates



Feed rate

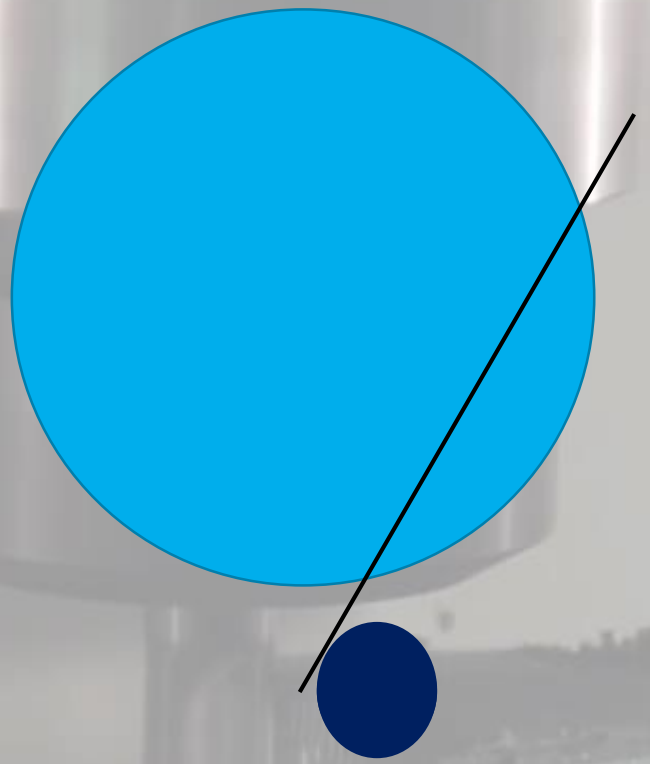


Course of force

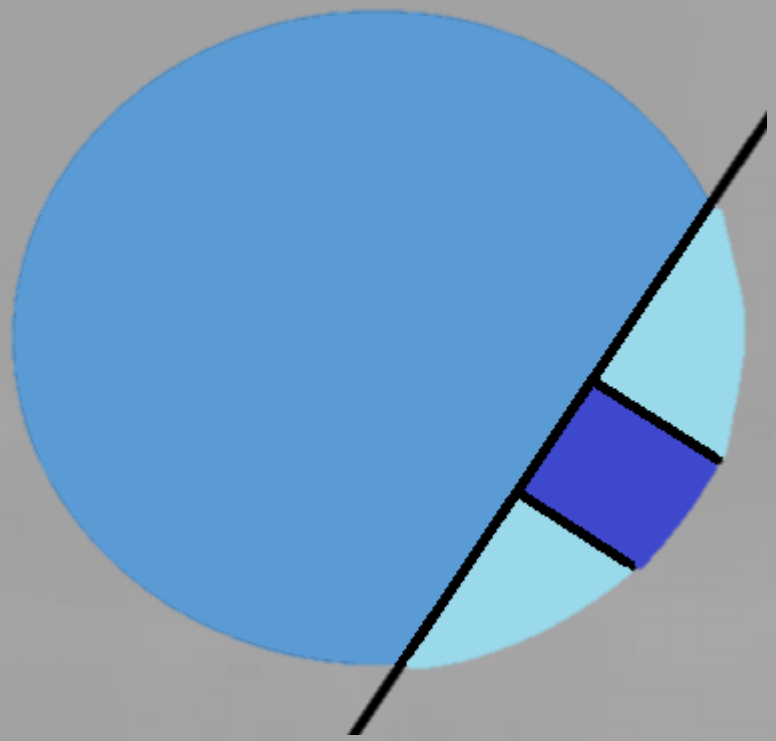
Δt =5%

constant feed

adaptive feed



Adaptive feed



Δt = 5% process time reduction
Δt = 0,02375 min per component

Savings per component x components per year = time savings
0,02375 min x 6.000.000 = Δt = 2.375 h

- Reduction of production time by 98.95 days per year (related to all 90 machines)
- Cost savings via machine hourly rate = 178,125 EUR per year

Total machining time per piece = 4.75 min
Processing time key surfaces = 0.475 min
(corresponds to 10% total processing time)
Machine hourly rate 75 EUR

CO_2-Savings with spike® and adaptive feed control

Time savings 2.375 h p.a.

Time saving x total load = power saving
2.375 h x 18 kW = 42.750 kWh

Power Savings **7.695 EUR**

Redction of CO_2-Emission **21,8 T**

Base load + process load = total load 18 kW/h
Energy costs 0,18 EUR/ kWh
CO_2-Emission 510g/kWh

Quality control – with spike®

Current:
100% quality control through human testing

Time expenditure p.M.	129,63 h
Costs	7.777,78 EUR

Optimization:
- Use of spike® for 100% quality control
- 50% quality control by random sample inspection

Time expenditure	97,22 h
Costs	5.833,33 EUR

Current costs p.M.	7.777,78 EUR
Costs after Optimization p.M.	3.888,89 EUR
Savings p.M.	3.888,89 EUR

Savings for 90 machines **350.000,00 EUR**

220 production days

Quality costs for 100% quality control	60 EUR/h
Duration for one workpiece	7 sec

Quality control - Reduction of rejects

- By using the **spike®,** the rejects can be reduced by **0.1%**.

Reduction of rejects p.M.p.a.	66,67 Stck.
x Sales price component	85,00 EUR
Increase in revenues p.M. p.a.	5.666,95 EUR
Total revenues for 90 Machines p.a.	**510.000 EUR**

Quantity p.a. 6.000.000 pcs.
Use of 90 machines
Stückzahl p.M. 66.667 pcs.

Total savings with spike®

Savings tool costs	532.800 EUR
Reduction of machine downtime	112.500 EUR
Savings in machine hours	178.125 EUR
Savings energy costs	7.695 EUR
Savings quality control	350.000 EUR
Reduction of rejects	510.000 EUR
Total savings	**1.691.120 EUR**

→Reduction of CO_2-Emisssion by 21.8 tons per year

Already with an improvement of the process time by 5% in the process section which is manufactured with spike (only 10% of the total process), 21.8 tons of CO2 emissions can be saved.

For applications with small and medium batch sizes

spike_connect_assist ▶ assistance system for machine operator

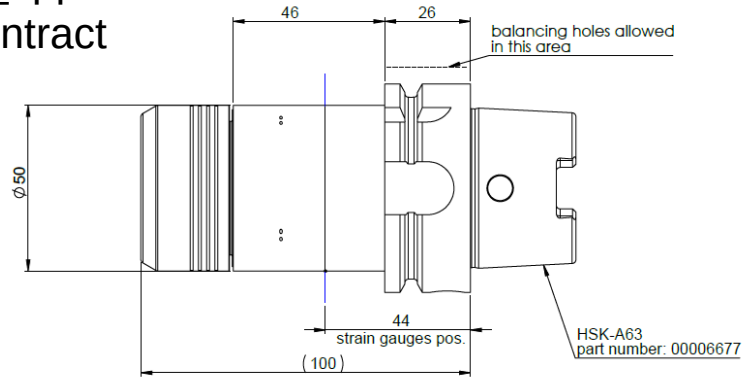
Benefit: „Assistance system“

- visual process support „process status at a glance“
- allows conclusions to be drawn about the relative utilization of the tool holder (%)*
- indirect wear detection (%)*
- manual protection against machine/process overload (%)*

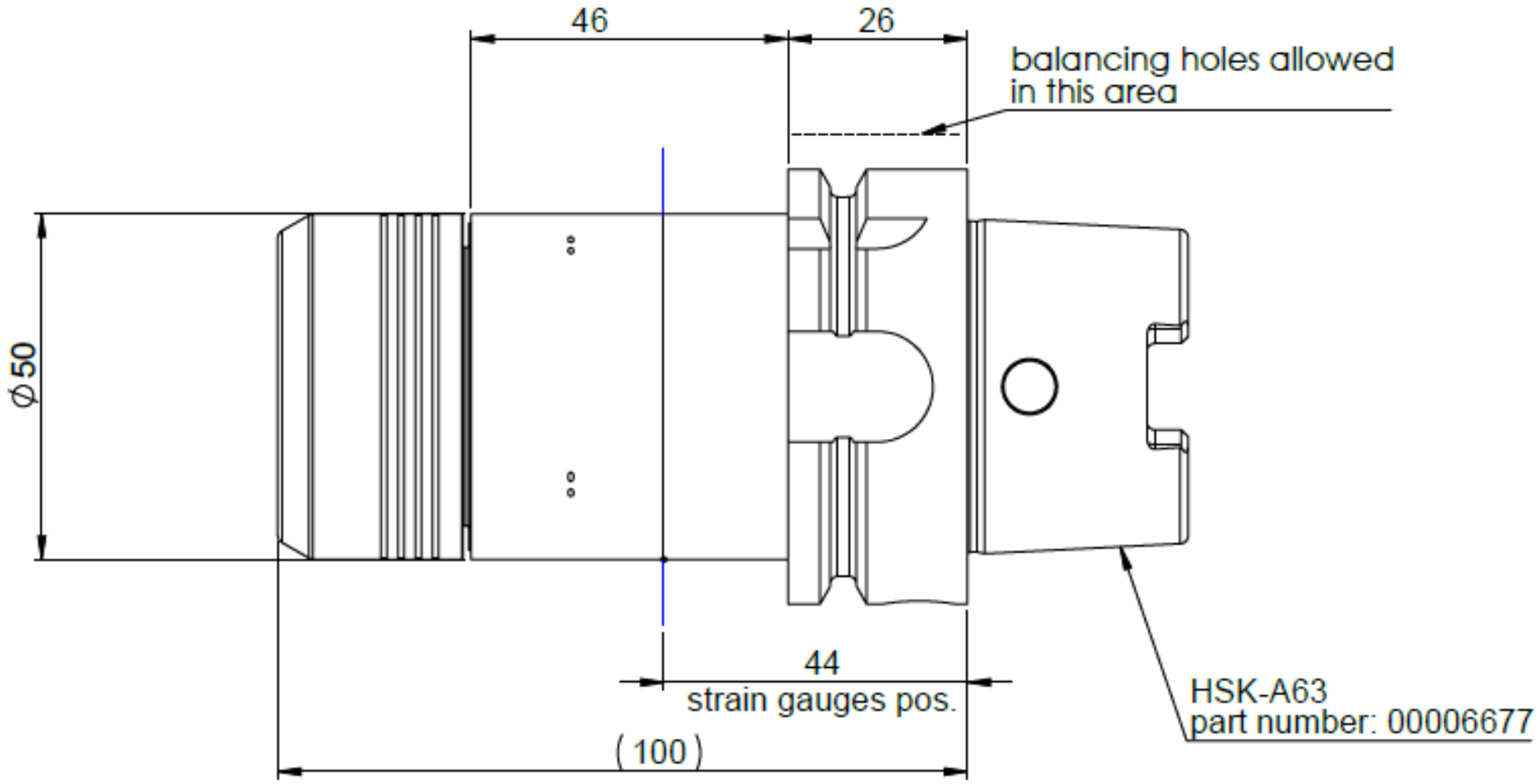
* % of the tool holder strength

Properties:

- no recording function only visualization
- upgradeable to spike®_mobile/custom
- plug & play setup in under 30 seconds
- small interfering components
- display via panel and spike®_app
- only available with a rental contract



spike_assist



For applications to optimise processes and tools

spike _connect_basic ▶ for flexible use from the trunk

Benefit: „Diagnostic system“

- solve process problems faster
- productivity and tool life optimization
- product development and optimization (tool, coating, cooling lubricant, process,
- machine,...)
- R & D (Institutes & Universities)

Properties:

- highest resolution (measuring precision)
- highest data transfer performance
- Plug & Play in < 2 min
- spike®_trigger - force controlled in previously defined measuring range
- Different sensitivity classes depending on requirements
- System compatible with many holder configurations

Application examples:

- MTU Aero - Process analysis & optimization of difficult-to-machine materials
- Hoffmann Group - Development of max. load indicators (spike_kpi)
- Ceratizit - Tool development
- Fraisa - Tool development

For applications in detailed analysis

spike_tool analyzer ▶ the quick and in-depth analysis of your measurement data

Benefit: „Analyse system“

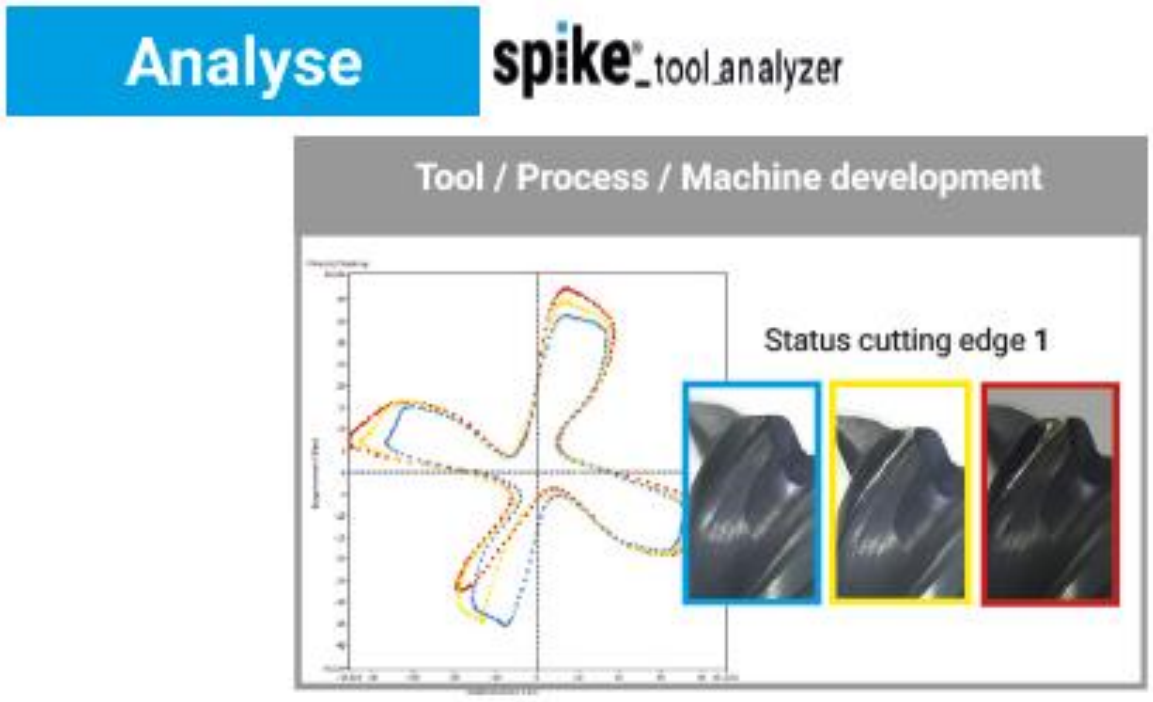
- single cutting edge comparison
- benchmarking
- analysis of specifi c process sections
- evaluate process setup
- offline use
- PC based licenses

Fields of application:

- Problem analysis in series production
- Series production for benchmark development
- Work preparation for creating cross-process evaluations & process settings

Properties:

- Offline use
- PC based licenses
- Long-term diagnosis with the help of Tool Life Plotting
- Angle and force value calculation



For applications in automated serial production

spike _connect_advanced ▶ with machine interface

Benefit: „Monitoring system“

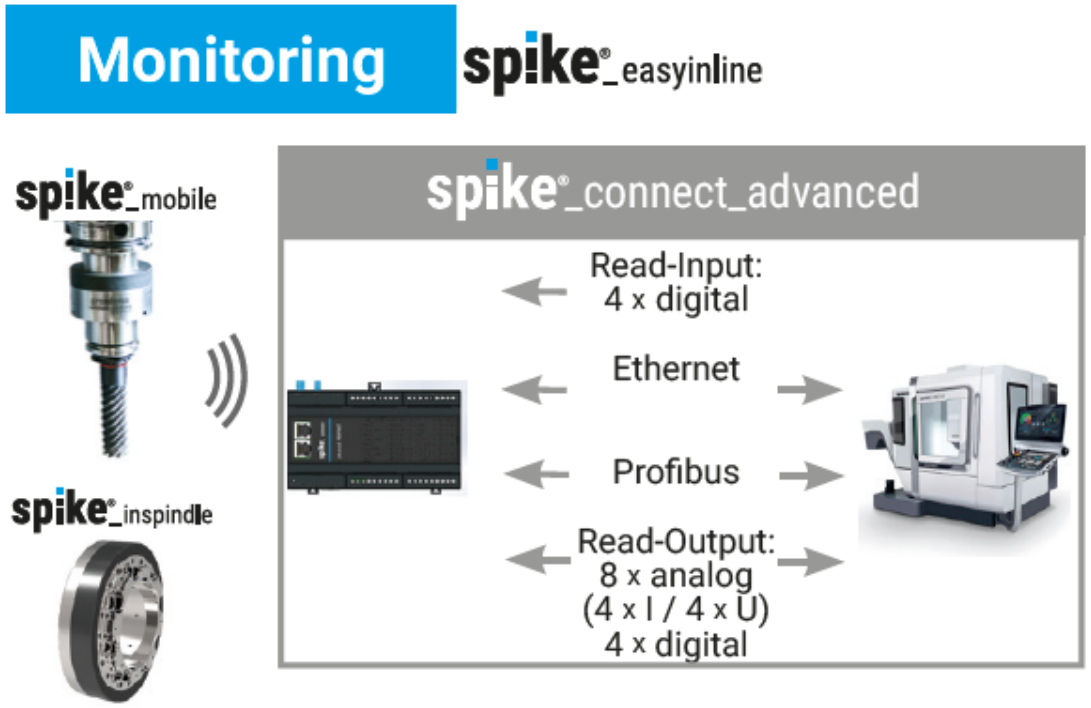
- 100% in-process quality control
- monitoring of shape and position tolerances (indirect)
- reduction of tool costs (via force-controlled tool change)
- avoidance of machine downtime
- adaptive feed control
- unmanned production

Properties:

- Full machine integration for all types with machine response
- Cycle time neutral / Can be used in 24/7 series production
- Compatible with external systems (e.g. ToolScope)
- I 4.0 integrable

Application examples:

- Automotive - Deburring at Robert Bosch GmbH
- Automotive - chatter mark recognition
- Automotive - Dimensional accuracy during turning
- Tools & Mould making - Ball milling cutters Finishing machining
- Aerospace - Knife head rough machining



*optional with the assistance system of ToolScope

Goals and features of spike_easyinline

promicron
wireless solutions

Process Control

- Process monitoring
  - Tool breakage detection
  - Trapped chips
  - Incorrectly clamped workpieces
- Tool wear monitoring
  (even for each cutting edge)
- Quality related monitoring
  - even with small tool diameters
  - Shape and position tolerances
  - High surface quality
- Adaptive feed control
  - Cut off force peaks to protect tools
  - Cycle time reduction

Machine Protection

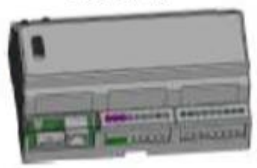
- Fast stop by detecting impact collisions
- Predictive Maintenance / Wear monitoring of feed axis
- Overload protection for spindle & machine tool

Digitization

- Easy process insight
- Live View of the shop floor & remote control
- Automatic evaluation & documentation of production data

Machine link

Funk



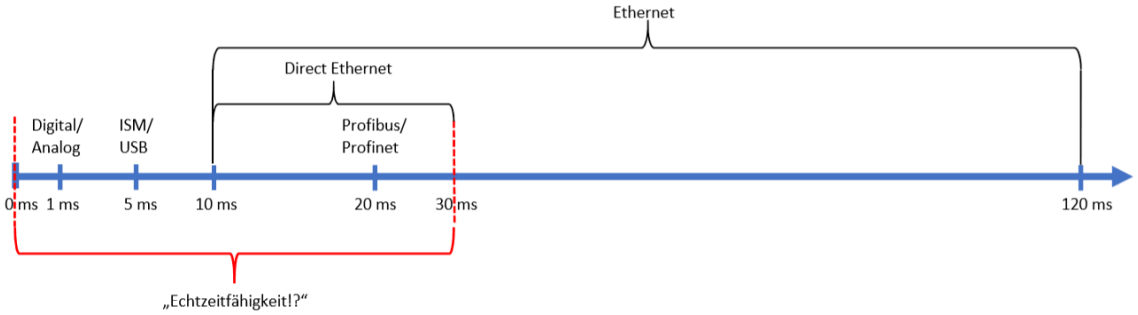
USB

Direct Ethernet

Read 4.0 - spike® - Befehle	
Befehl	**Dauer [ms]**
Wake up	max. 3000 ms
Quick – Tara	100 ms
Normal – Tara	1000 ms
Messung Start	max. 2 ms

Profibus
Ethernet

Profibus
Profinet
Ethernet



spike®

promicron
tool control center

Steps	1.	2.	3.
Actions	**Identification / Analysis** **spike_mobile** **connect_basic** **To do:** **1. Record the process** **2. Analyse the process** **3. Definition of the benefit** **4. Calculate amortization**	**Long Term Diagnose** **spike_mobile** **with machine interface** **connect_advanced** **To do:** **1. Start long-term diagnosis** **2. Detect process fluctuations** **3. Define Monitoring Parameters / KPIs**	**Machine Integration** **spike_mobile** Permanent installation in machines with workpiece 1 or **spike_inspindle** Permanent installation in machines with workpiece 1 **spike_mobile** if necessary combination with spike_inspindle for particularly sensitive processes
Objective	**Identification of optimization potential** **=> spike_diagnose report**	**1. Long-term plausibility check optimization potential** **2. spike_kpi Determination**	**1. Dynamic tool change** **2. 100% quality control** **3. Form and position tolerances** **4. Machine integration**

References

Our References

BOSCH
Technik fürs Leben

CERATIZIT
GROUP

passion
for precision
fraisa

Hoffmann Group
Tools to make you better

DC
THREADING
TECHNOLOGY

HEULE+
PRECISION TOOLS

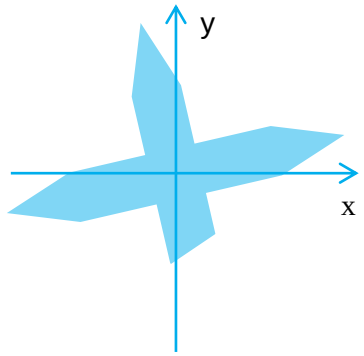
DMG MORI

MTU
Aero Engines

Overview spike_kpi

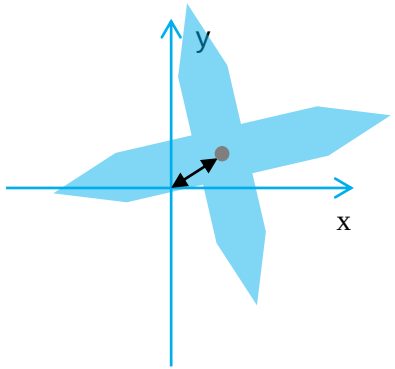
promicron
wireless solutions

Symmetry



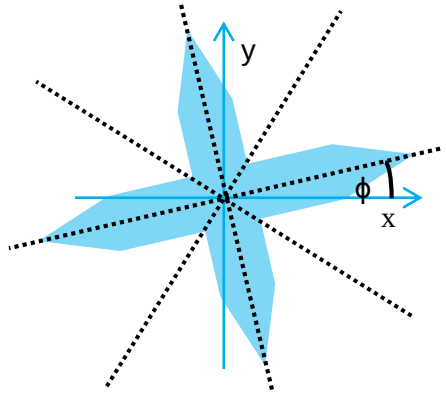
tool breakage, tool quality

Bending moment centroid



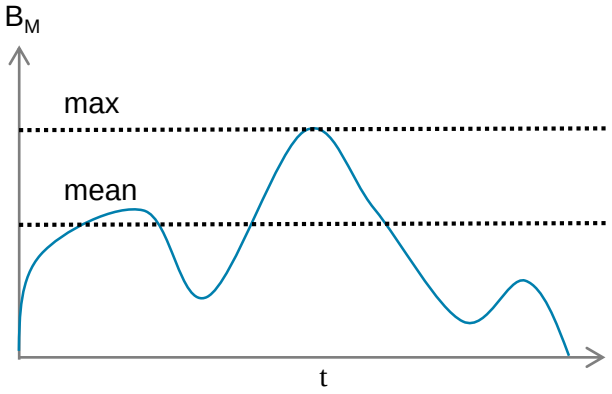
unbalance

angle to main axis



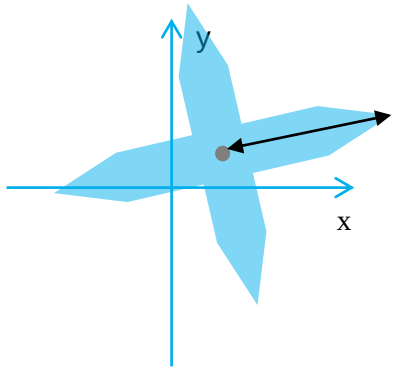
wear

max & mean B_m, F_z , M



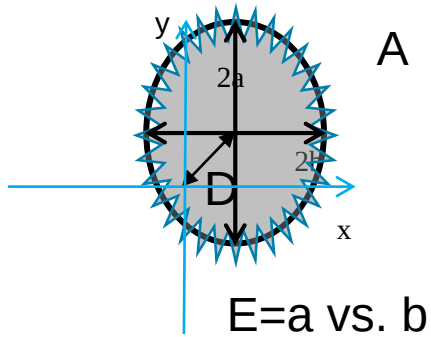
wear, chatter, overloads

Bending moment amplitude



wear + unbalance

Ellipse area A, eccentricity E & deviation coefficient D



A

E=a vs. b

A: wear, chatter, overload
E: tool breakage
D: unbalance

Example spike_kpi for tool breakage detection

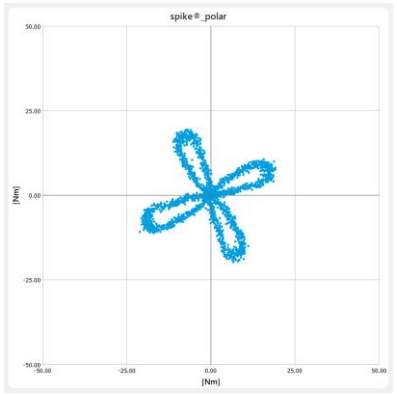
promicron
wireless solutions

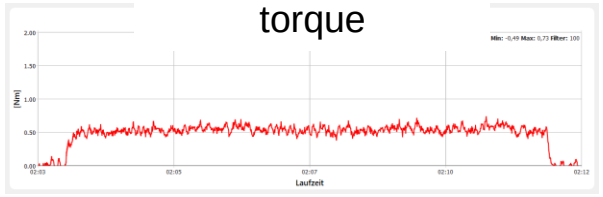
spike®_polar

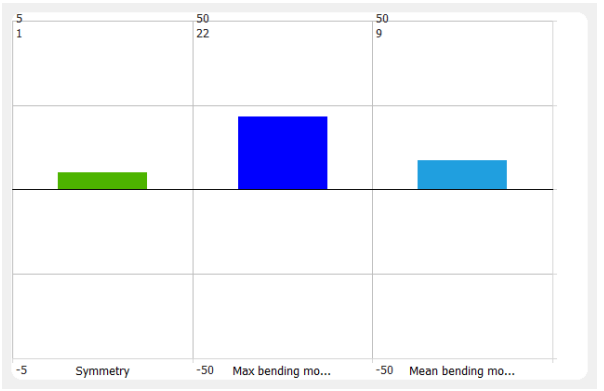
raw-data

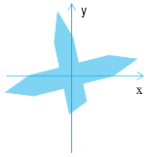
spike_kpi calculation by 1000 values

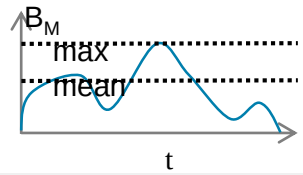
new tool



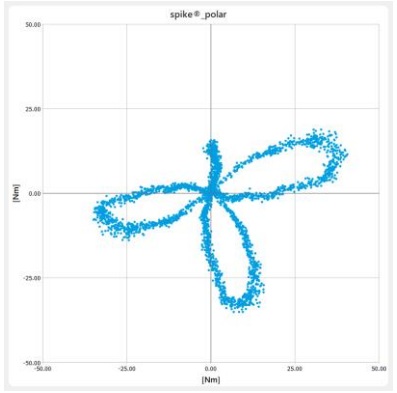


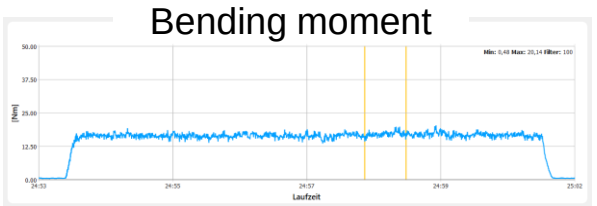


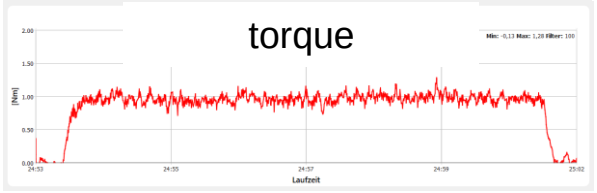


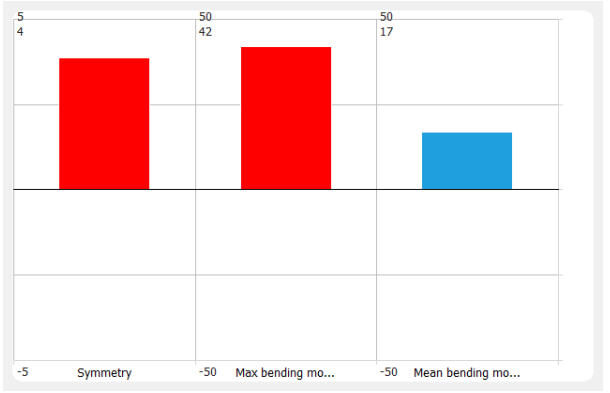


broken tool









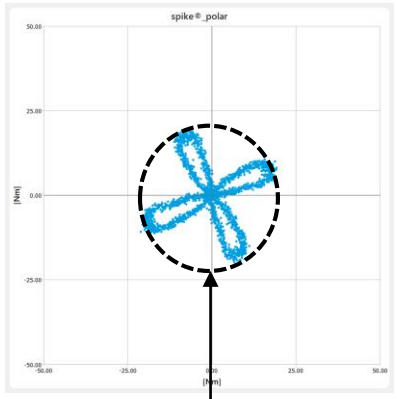
Example spike_kpi for tool wear determination

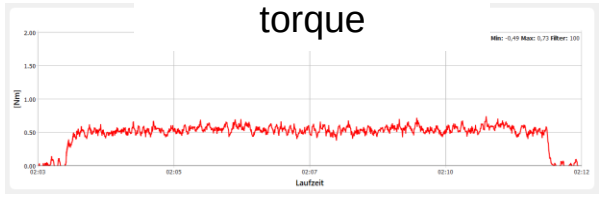
spike®_polar

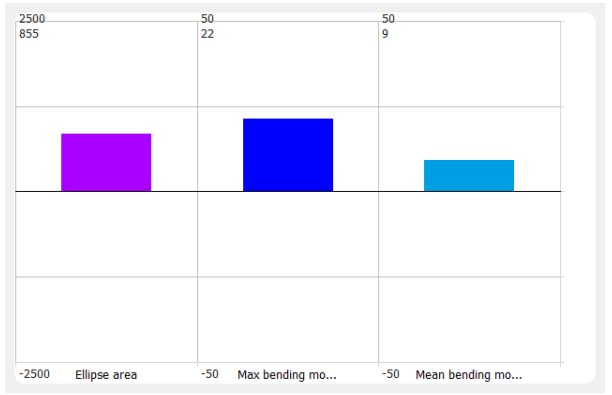
raw-data

spike_kpi calculation by 1000 values

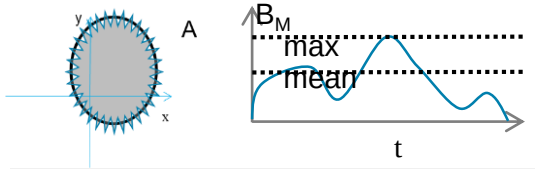
new tool



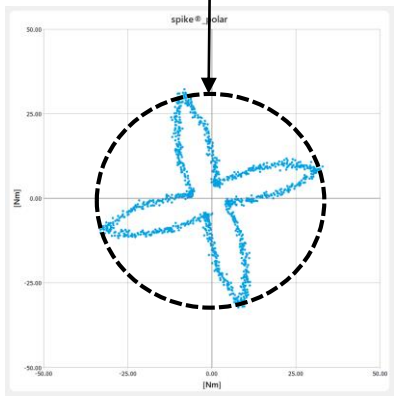


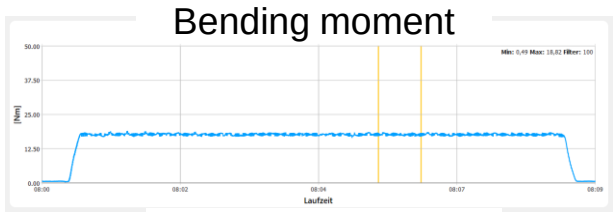


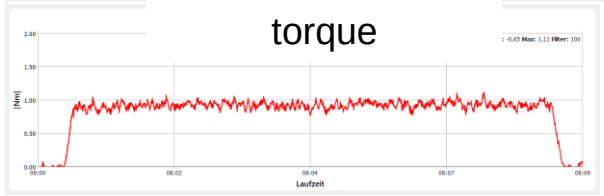
Ellipse area determination for tool wear monitoring

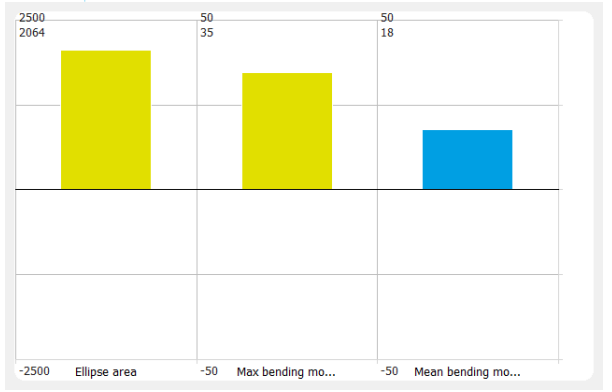


worn tool



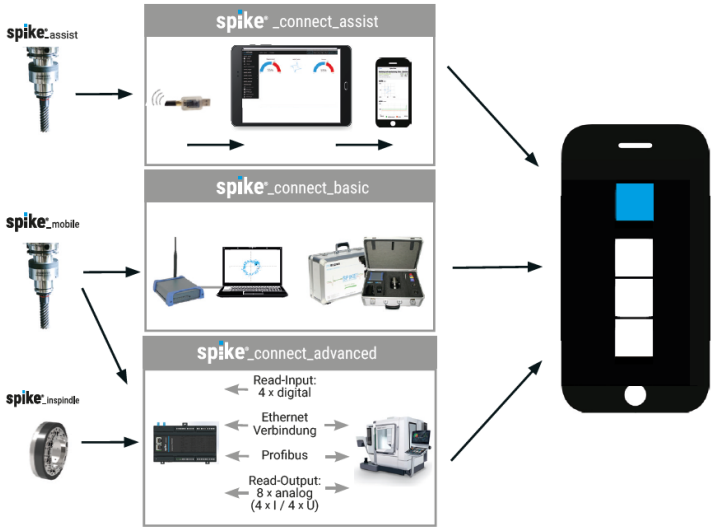






Tool Control Center Software – new in January 2020

Function 3: monitor via preset limits for spike_kpis with notofications in spike_app



spike®_app

- spike®_products compatible
- push & pull messages
- alarm function
- report function (last 60 seconds)
- monitoring of any number of panels