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Real-time monitoring of the thin diamond wire manufacturing process

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**Kean Diamond Wire Corp., North Tonawanda, USA

List

KEAN DIAMOND WIRE

Einar List

- Diploma 1976 and doctors degree 1986 from the Technical University Ilmenau
- Since 1996 head of R&D in the Vollstaedt-Diamant GmbH in Germany.
- Sorting, grading and characterization devices for diamond and cBN

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Einar List (cont.)

- engineering bureau as garage company since 17 years
- technical solutions in software and hardware for applications in telecommunication, human genomic research, nuclear research, wire drawing and diamond tool manufacturing

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Al Bluemle

- research and development of new products at Aglade Industries
- with Niabraze LLC developed experience in the electroplating and brazing of diamond abrasive tools
- the last two years he has spent developing a diamond wire product with Kean Diamond Wire Corp
- he has contributed with process development, product testing, product evaluation, and marketing

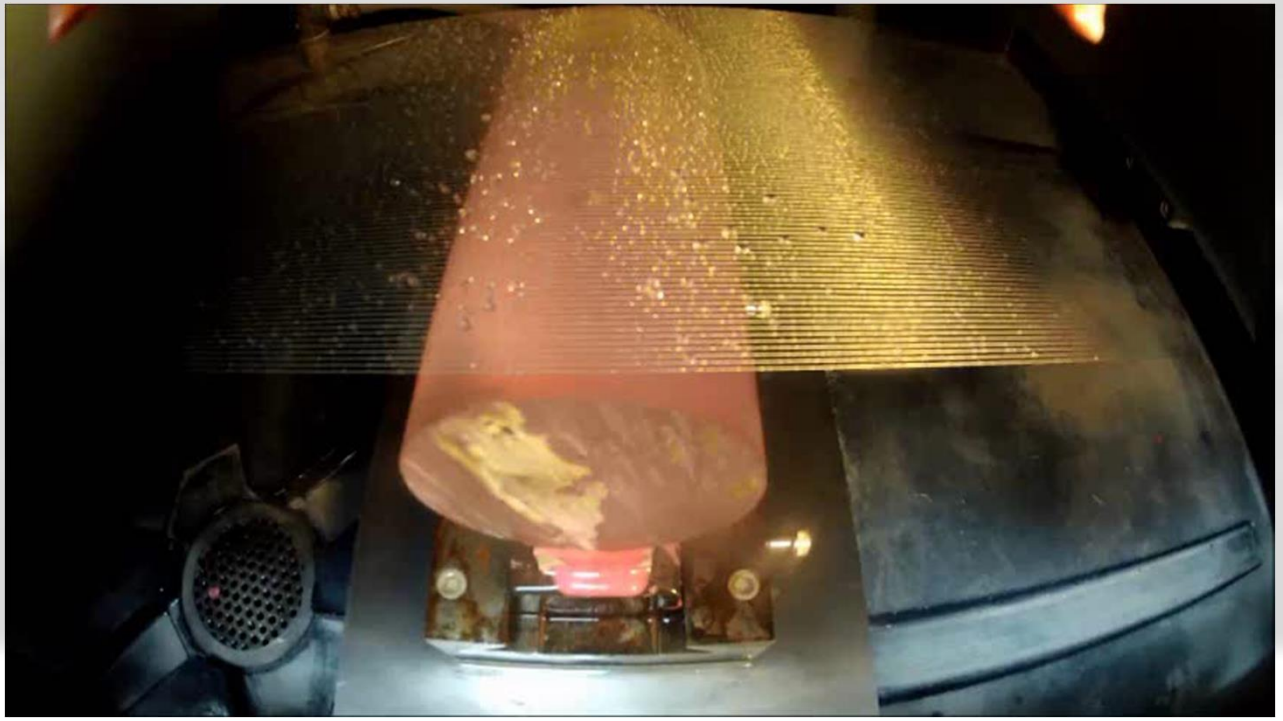
KEAN DIAMOND WIRE

Content

- Application of thin diamond wire
- Factors for wire performance
- Challenges for inline measurement
- Measuring diamond on the wire
- Parameters for describing the wire
- Application experience
- Offline measurement of wire loops

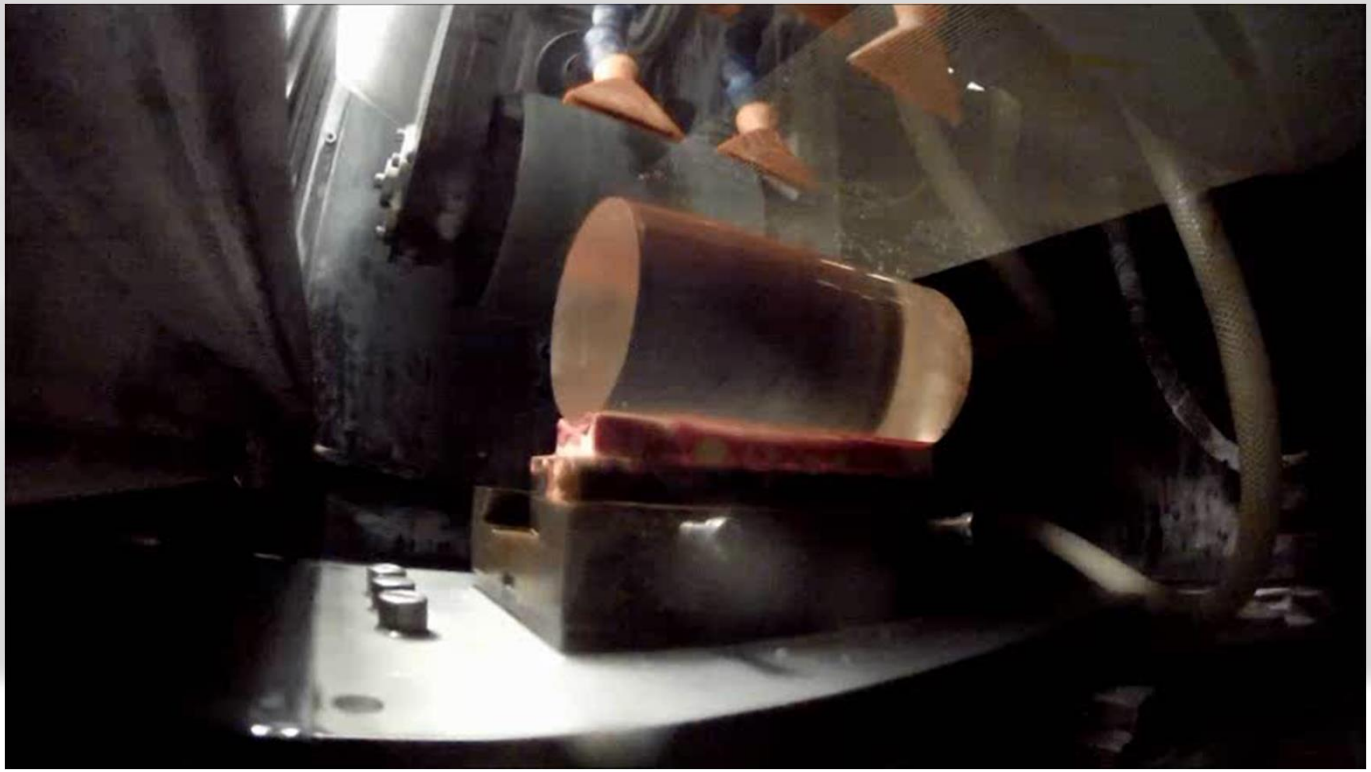
Thin diamond wire application

- Cutting hard and sensitive material
- Sapphire
- Silicon
- Glass
- Single wire (loop) and multi-wire



Thin diamond wire application parameters

- Cut rate
- Kerf loss
- Lifetime
- Roughness
- Stress
- Price



Thin diamond wire manufacturing

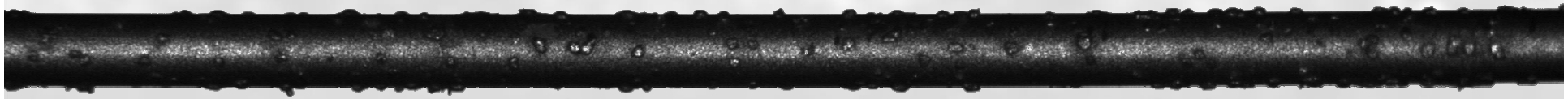
- Raw wire treatment
- Diamond treatment
- Diamonds attachment
- Diamond fixation
- (Electroplating, Plastic or rubber coating, Brazing)

Thin diamond wire parameters

- Core material, strength, fatigue strength
- Diamond type, size
- Diamond retention
- Coating to core bond
- Diamonds per length
- Diamond distribution
- Geometry (diameter)

Controlling the variable parameters

- Diamonds per length
- Diamond distribution
- Geometry (diameter)



Conditions:

d= 0.0X … 1 mm

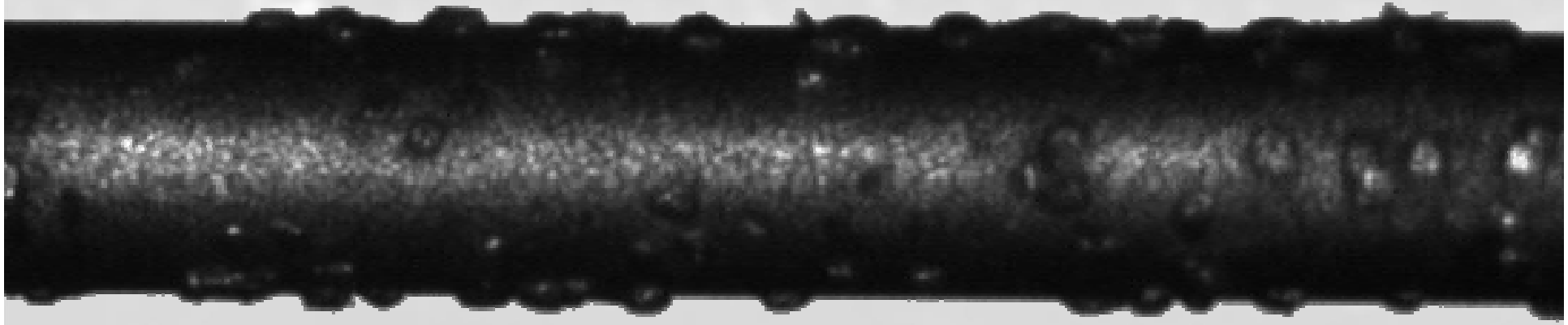
V = 0.5 … 60 m/min

Conventional method

- A few samples from the end of the wire
- Micrometer for diameter inspection
- Microscope for diamond count and distribution
- These samples must represent the whole length!

Continuous inline inspection requirements

- Continuous sampling of the wire from beginning to the end



- Micrometer resolution
- Real-time data output
- Data archiving

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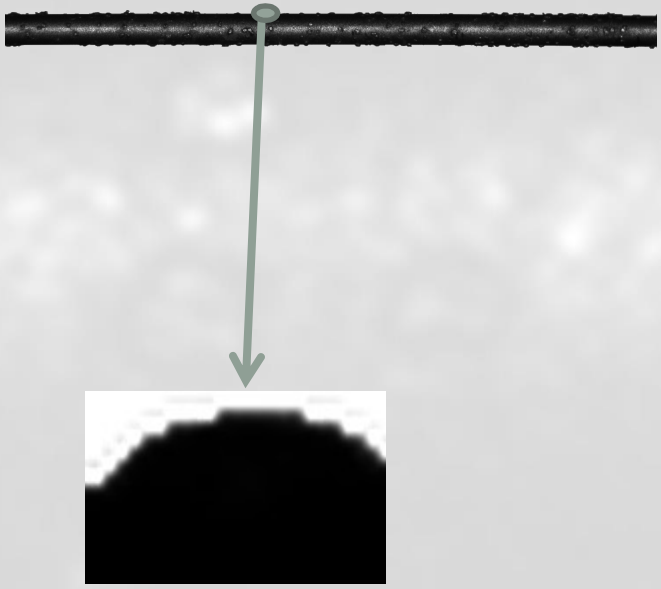
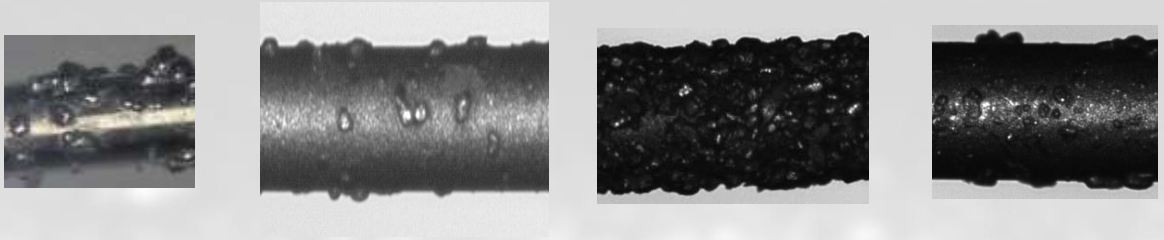
The technical challenge:
1 m/s ist FAST !



1 m/s in micro is in macro 9 km/s ~ 5,600 mph
(first cosmic speed is 7.91 km/s)

The technical challenge part2:



- Various surface structures
- Various surface of the diamonds (coated, uncoated)
- Vibrations change position and focus

- Measuring results must not vary if the optical properties of the wire components change
- Minimum adjustment requirement, not many knobs!

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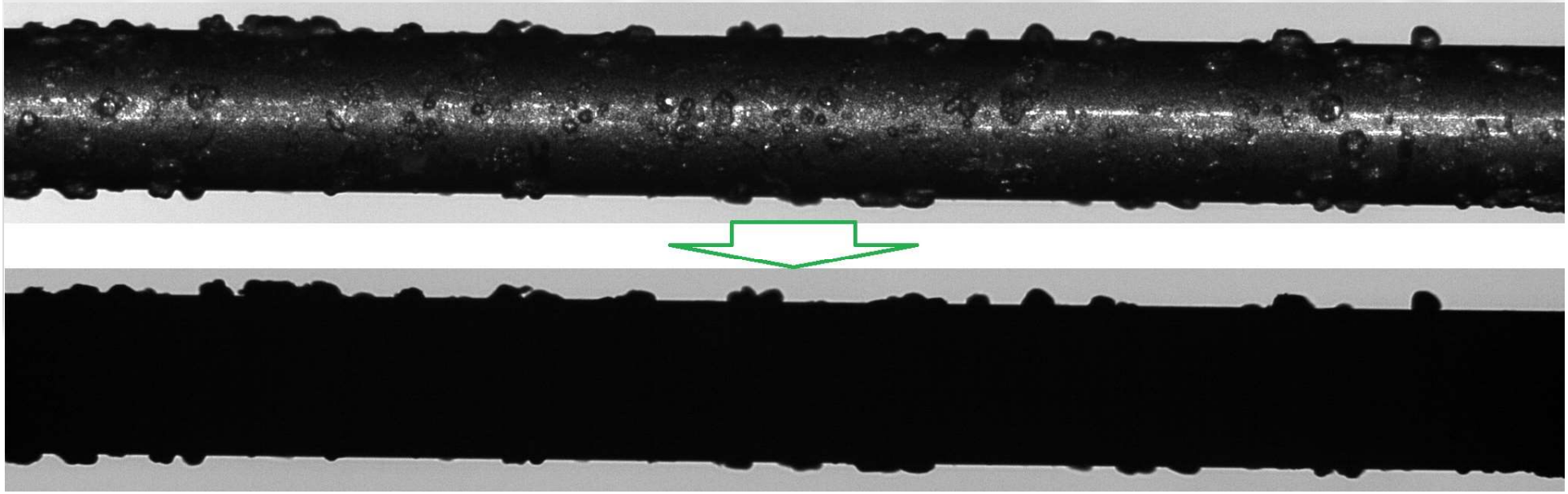
The solution:

- Profile projection setup
- Strong backlighting allows for very short exposure time
- Telecentricity eliminates errors from defocussing



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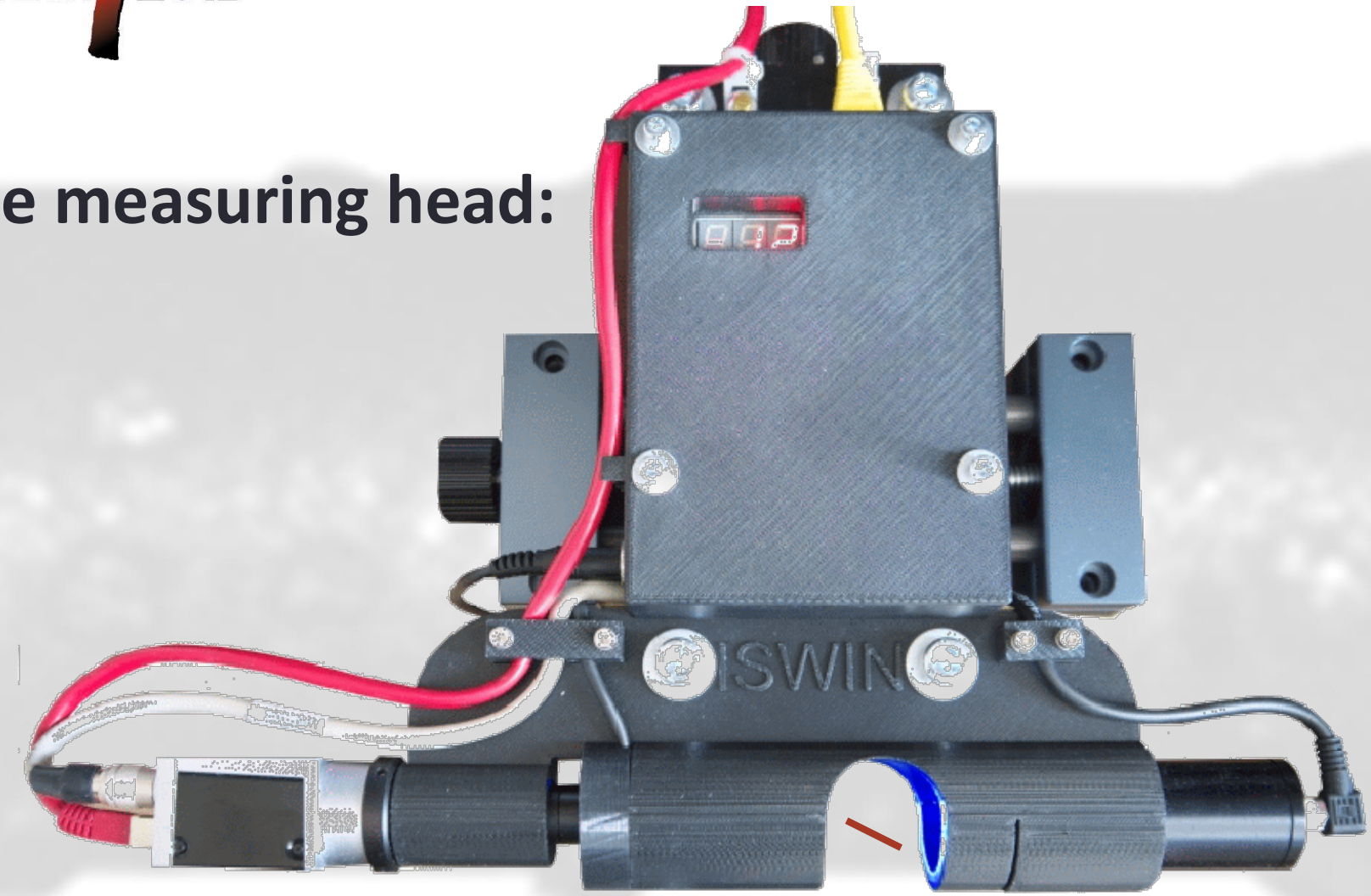
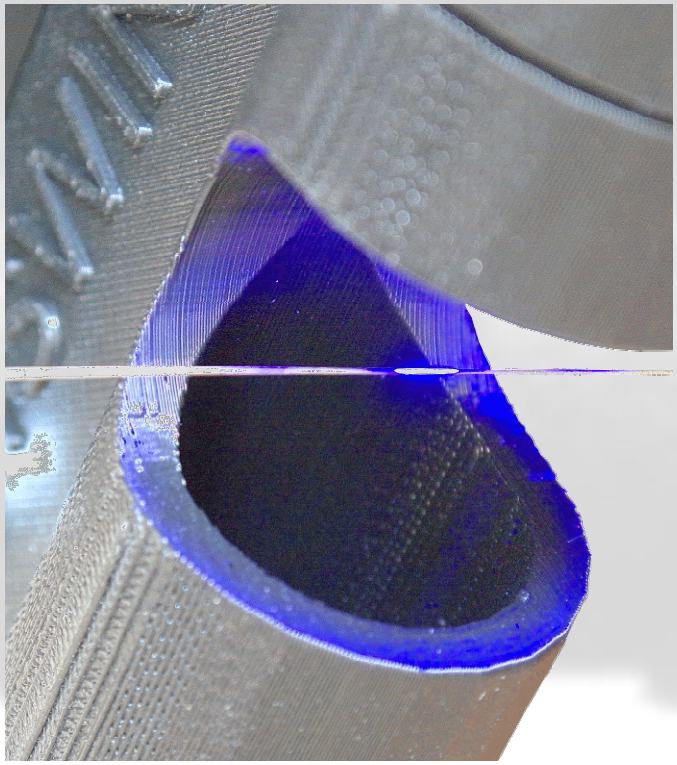
The measuring head:



Camera Optics Wire Backlighting

ISWIN = Inline Saw Wire Inspection



Standard optics:

- resolution 1.4 µm / pixel
- Field of view:
  - Width 2.87 mm
  - Height 1.5 mm

High magnification optics:

- resolution 0.9 µm / pixel
- Field of view:
  - Width 1.84 mm
  - Height 0.98 mm

ISWIN software

- Locate the wire
- Determine the wire angle
- Separate the diamond layer from the wire body
- Analyse the diamond layer
- Record the results
- Check for alarm conditions

ISWIN live

Selectable span for moving average or peak detection

Calculation method selectable for every parameter:

Averaging
Minimum detection
Maximum detection

Records the data into an EXCEL file

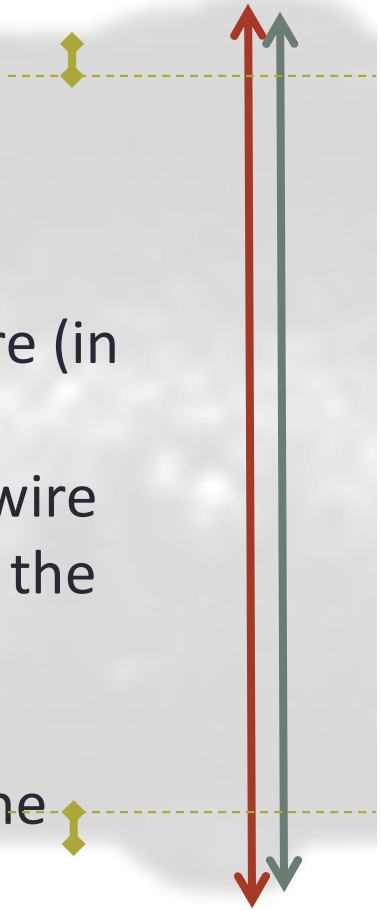
Displays the history

Allows scrolling in the history

ISWIN parameters

x – linear dimensions related to the wire

- **xNi** – thickness of the Ni-layer around the core wire (in case of electroplating technology)
- **xDm** - Maximum wire diameter (Maximum outer wire diameter measured between the highest peaks of the particle layer)
- **xDe** - Effective wire diameter (Effective outer wire diameter, measured between the main peaks of the particle layer



ISWIN parameters

x – linear dimensions related to the particle layer

- **xS** – Spacing between the particles on the upper and lower wire edges
  - **xSmin** - minimum spacing
  - **xSmax** – maximum spacing
  - **xSavg** – average spacing
  - **xSsd** – standard deviation of the spacing

ISWIN parameters

mP – diamond mass (volume) per length

Improved calculation of mP:

- calculate the sum of areas protruding from the metal surface
- calculate the equivalent layer thickness which gives the same area
- calculated the volume of the layer per meter of wire length
- this value is proportional to the particle weight per meter

mP = Volume of the red "tube wall" per meter of length in mm^3/m

ISWIN parameters

nP – Count of fully visible particles per length

- Top edge
- Bottom edge
- Average

- Particle size is product specific parameter

ISWIN parameters

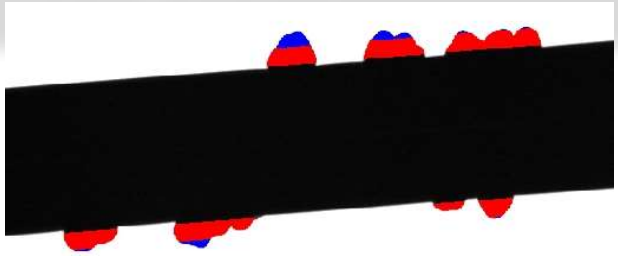
rCa – relative values for the expression of axial clustering

- **rCa_1 -** Axial clustering, measured as maximum spacing divided by average spacing between the particles, distance measured x µm above the bond surface
- **rCa_2 -** Axial clustering, measured as the standard deviation of the spacing divided by the average of the spacing between the particles, the spacing is measured between fully visible particles which are bigger than the defined minimum size

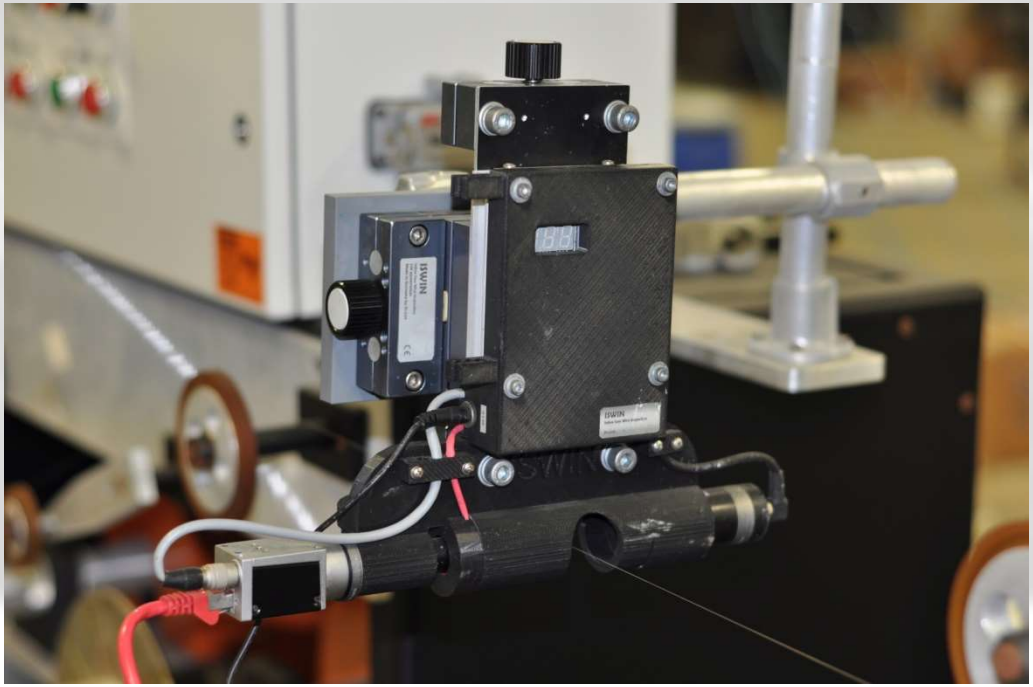
ISWIN parameters

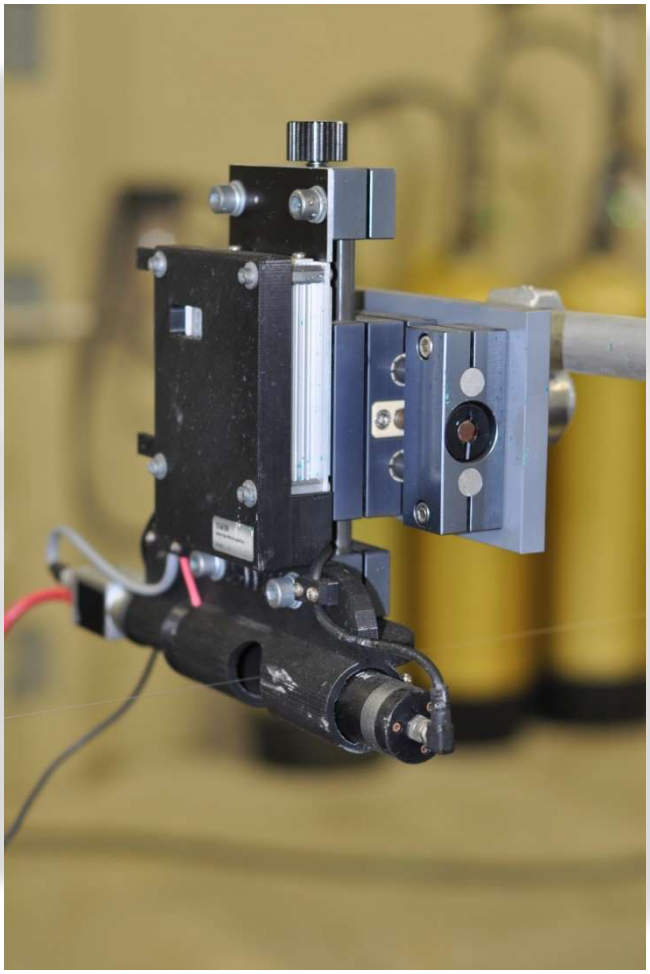
rC – relative values for the expression of clustering

- **rC -** amount of particles which are bigger than the maximum value (defined by the maximum particle size) relative to nP
- **rCr -** amount of particles area outside the allowed range (which is defined by the “maximum particle layer thickness” in the product definition) relative to mP -> radial clusters

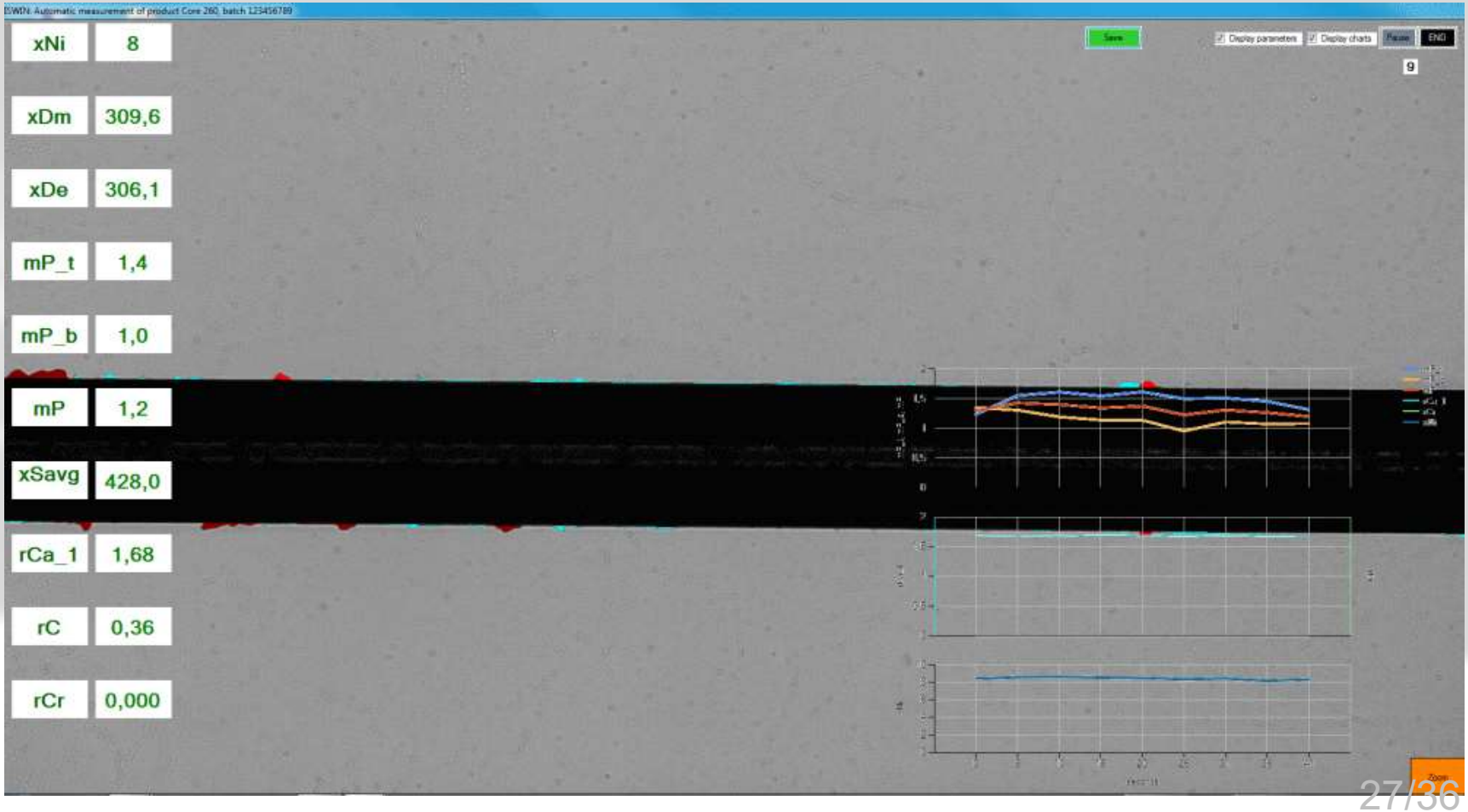


ISWIN online



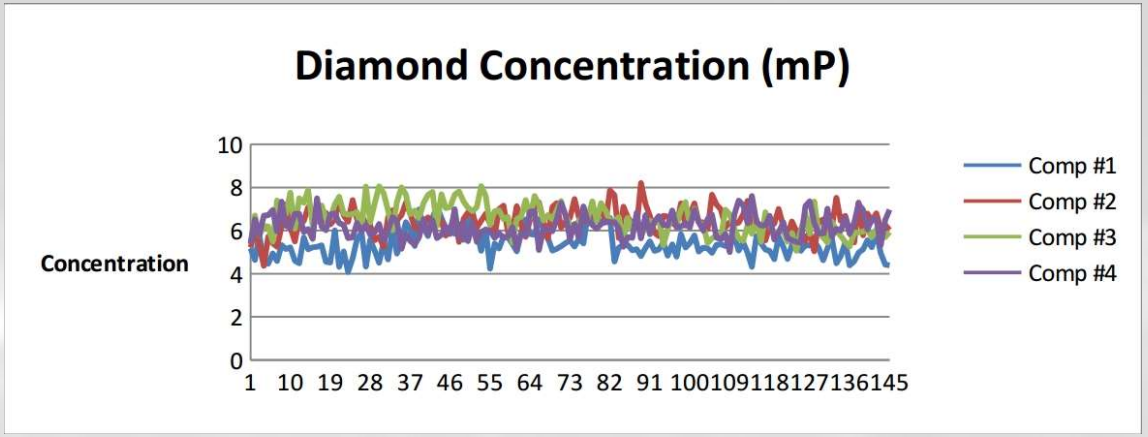


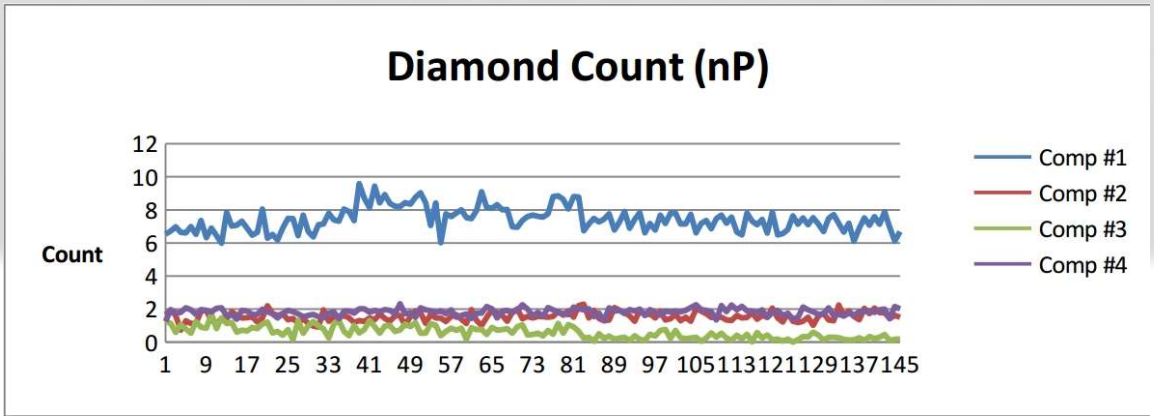
ISWIN inline



ISWIN in the product development

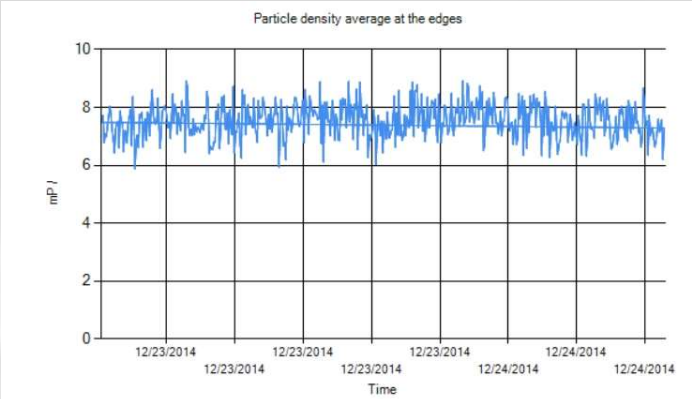
" Some wire parameters are very consistent between competitor's wire, while other parameters varied significantly ...
Each wire had it's own unique characteristics and no two were exactly the same."



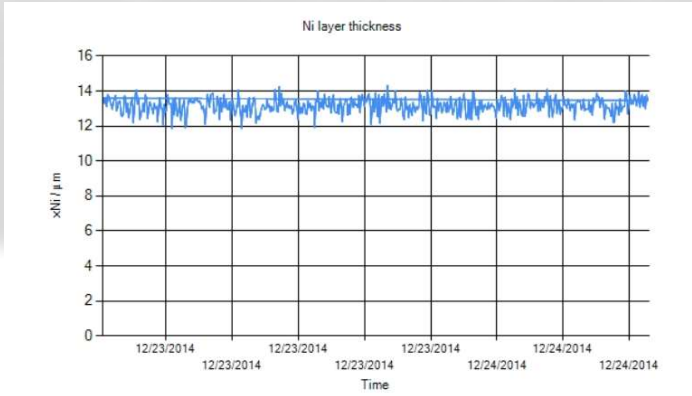


ISWIN in the manufacturing control

"The real-time, inline monitoring of our wire during production allows us to make adjustments on the during production to ensure that our product never sways out of specification. ISWIN monitoring has allowed us to confidently create a consistent product for very long periods of time.."



Average mP of 7.5

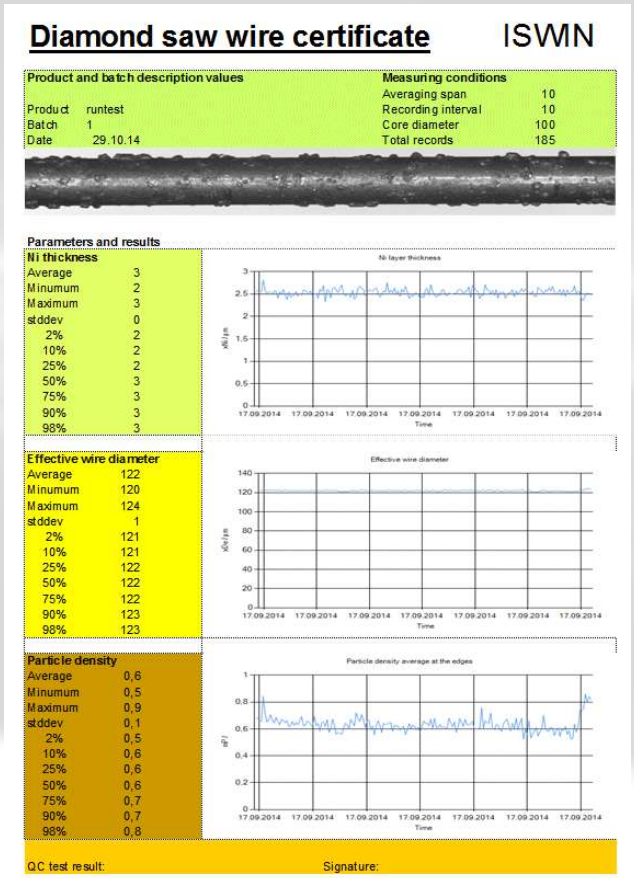


Average Ni Thickness of 13.2µ

ISWIN data as product documentation?

- Documentation template easy to define
- Template easy to fill with data from the actual wire

- QC document for inhouse use presents statistics and graphs for all parameters



Diamond saw wire certificate ISWIN

Product and batch description values		Measuring conditions	
		Averaging span	10
Product	runtest	Recording interval	10
Batch	1	Core diameter	100
Date	29.10.14	Total records	185

Parameters and results

Ni thickness	
Average	3
Minumum	2
Maximum	3
stddev	0
2%	2
10%	2
25%	2
50%	3
75%	3
90%	3
98%	3

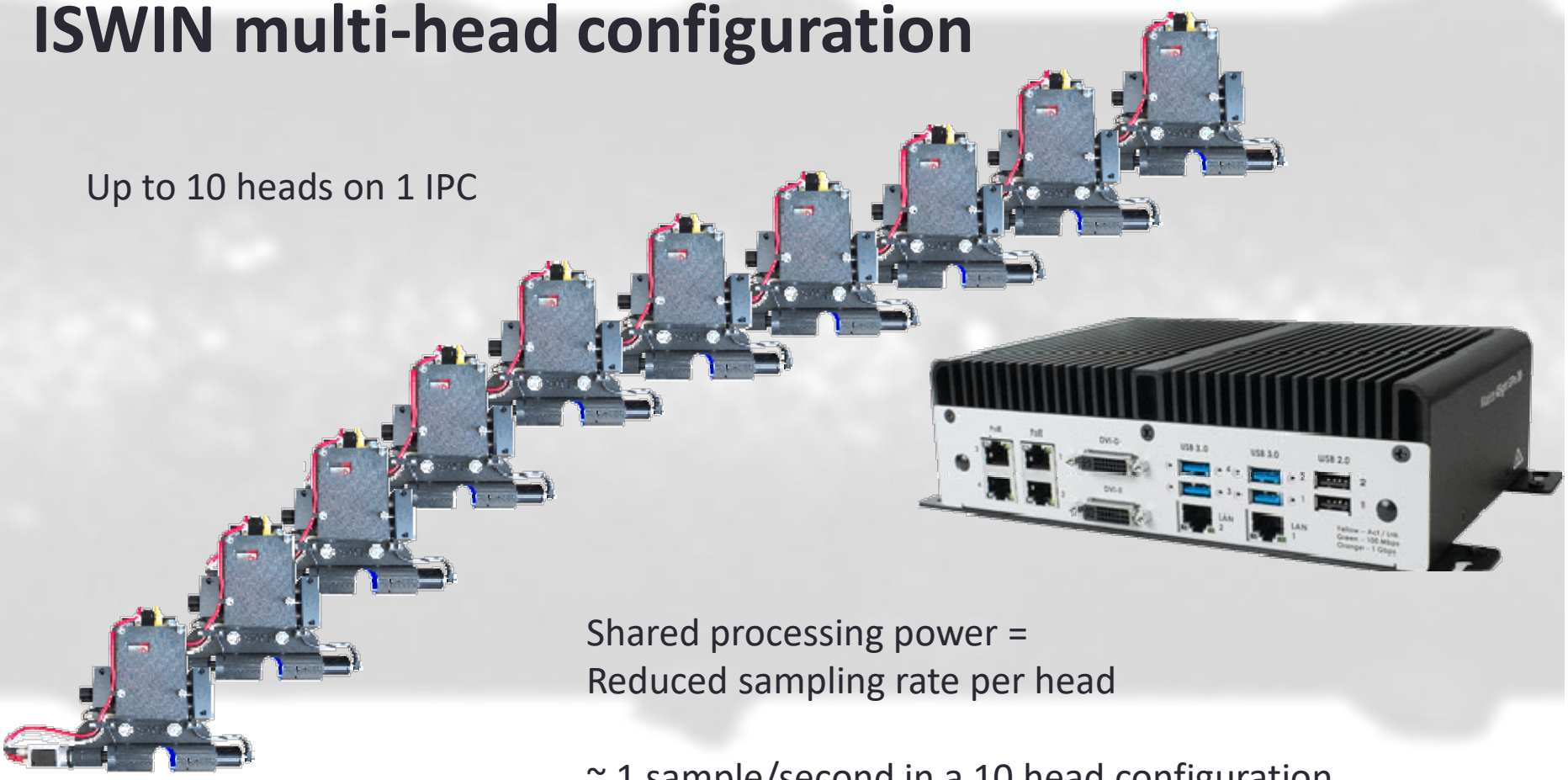
Effective wire diameter	
Average	122
Minumum	120
Maximum	124
stddev	1
2%	121
10%	121
25%	122
50%	122
75%	122
90%	123
98%	123

Particle density	
Average	0,6
Minumum	0,5
Maximum	0,9
stddev	0,1
2%	0,5
10%	0,6
25%	0,6
50%	0,6
75%	0,7
90%	0,7
98%	0,8

QC test result: Signature:

ISWIN multi-head configuration

Up to 10 heads on 1 IPC



Shared processing power =
Reduced sampling rate per head

~ 1 sample/second in a 10 head configuration

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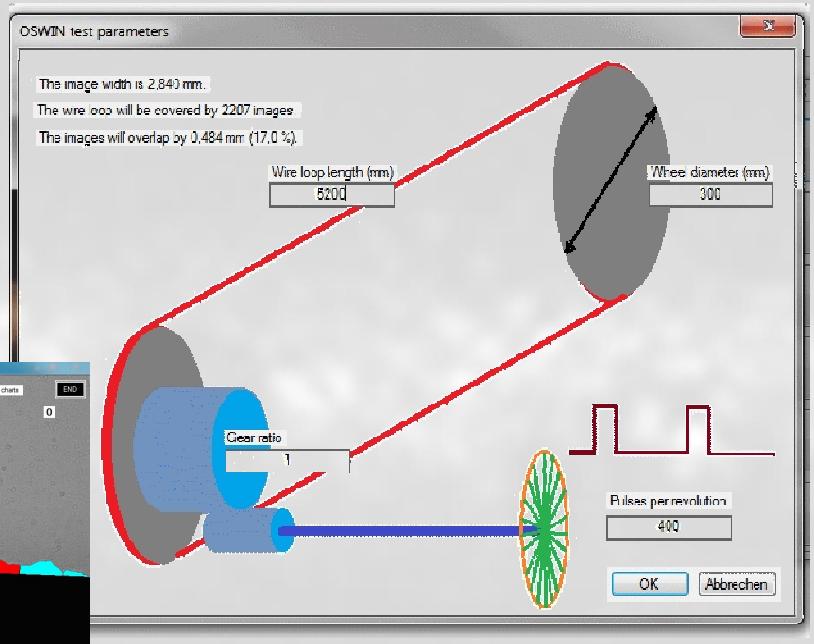
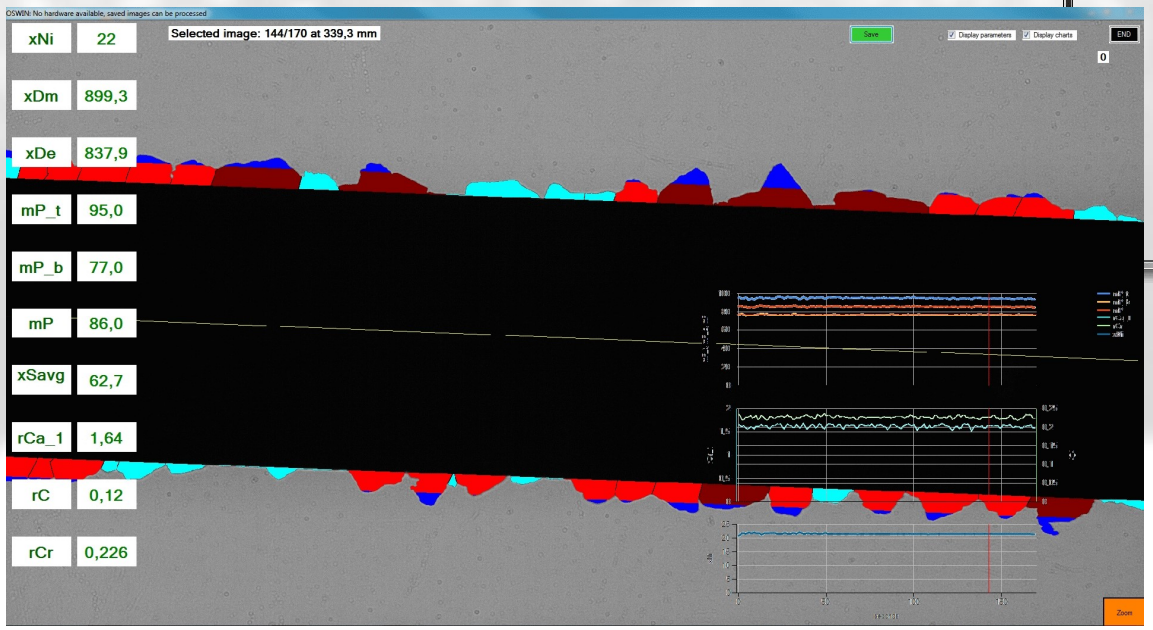
How about short, but endless wire?

ISWIN for offline inspection of wire loops = OSWIN

- triggered, equidistant image acquisition over the whole length
- followed by image sequence analysis





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Conclusions

- Inline monitoring leads to a more consistent product
- Consistent data prove a tightly controlled product
- In future it might become a sales argument to accompany the wire spool with some statistical data
- Offline wire analysis for product development and wear studies is possible

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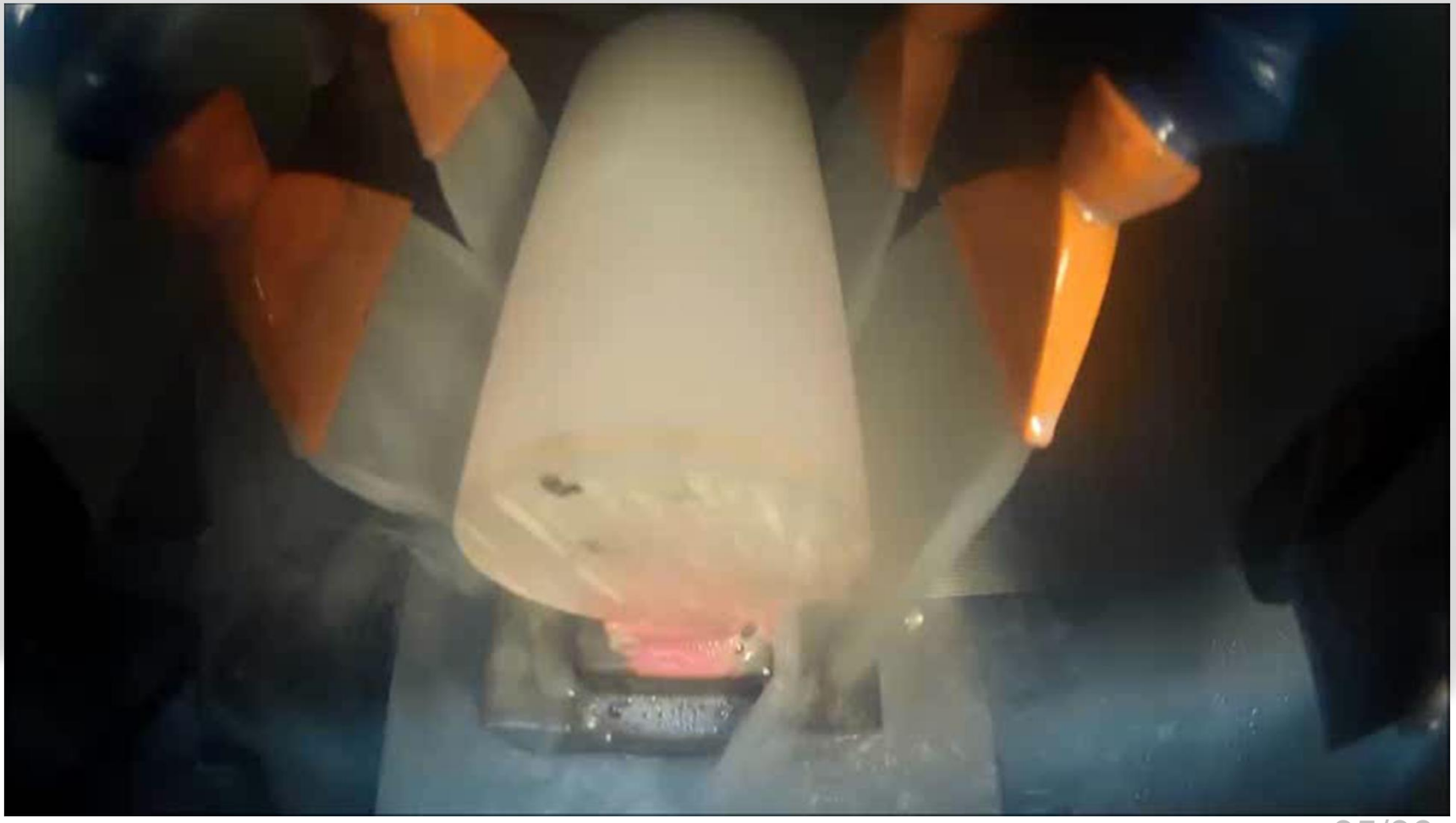
Meanwhile the wire has done a great job



Thank you!

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