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Form measurement for aero engine components - contact or non-contact?

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Form measurement

- **Is it round?**
- **Is it straight?**
- **Is it a combination of these?**
 - **Is it spherical?**
 - **Is it flat?**
 - **Is it cylindrical?**
 - **Is it conical?**



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Free form measurement

- **Is it really a 'free' form?**
 - **We want to know if it conforms to what the designer asked for**
 - **We want to know what shape it is, but we have no master to compare it with**



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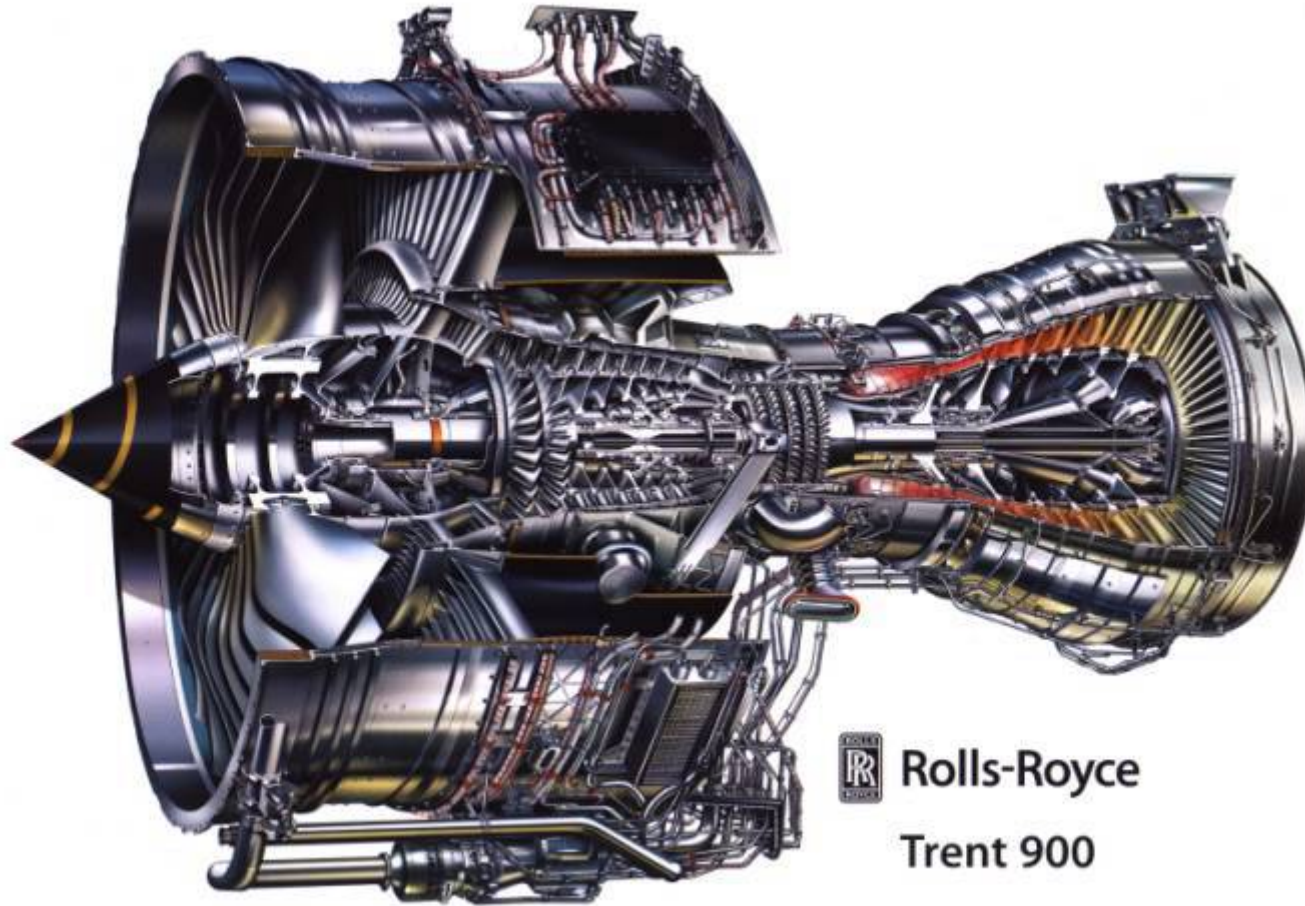
Why?

- **Do we need to know everything about the surface, or can we make some assumptions about it?**
- **What is the basic function of the surface?**
 - **Aesthetics**
 - **Fit**
 - **Function**



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Trent 900 – Airbus A380 engine



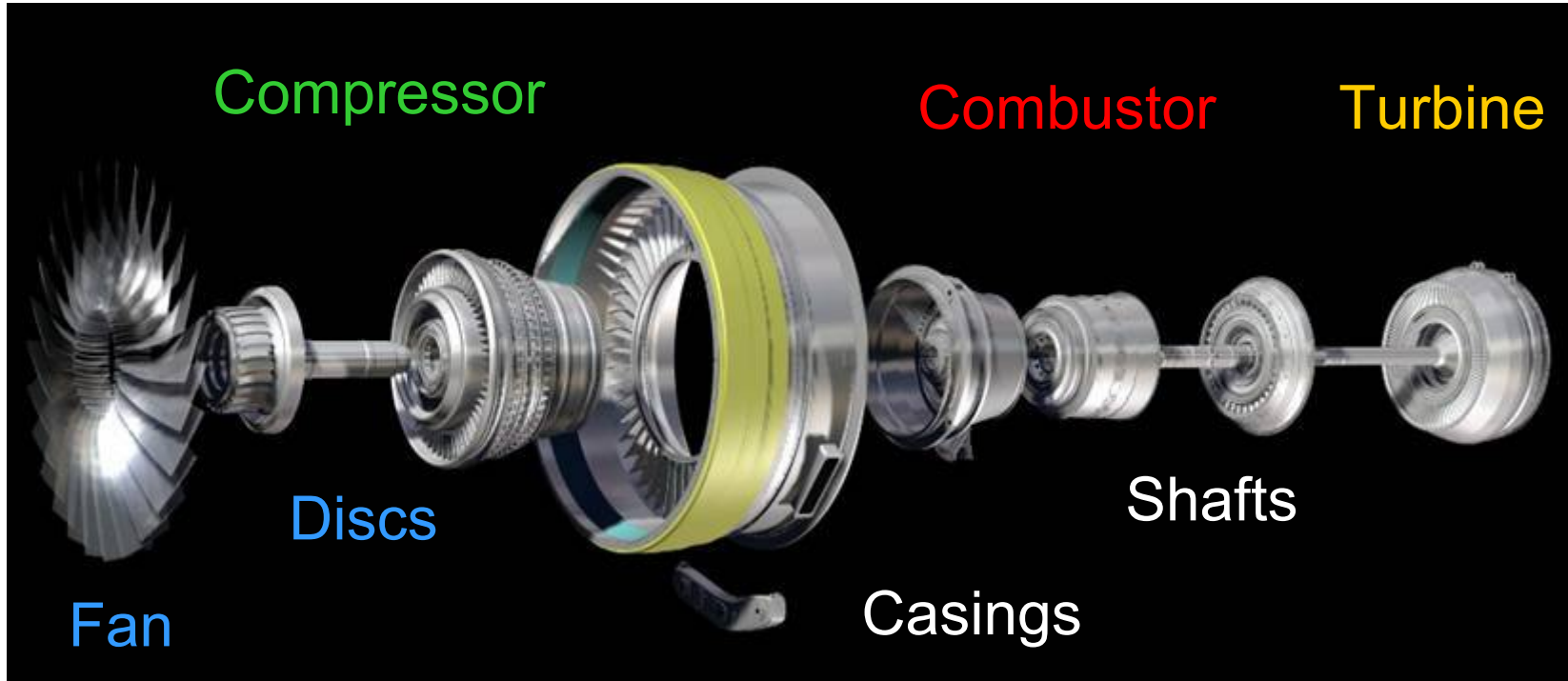
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Trent 900



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What do we make that needs to be measured?

- **Answer: All of it!**
 - **100 commodity families**
 - **3,000 components (excluding fasteners)**



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Fan assembly



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Compressor rotor assembly



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HP compressor blisk



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Turbine blade root form



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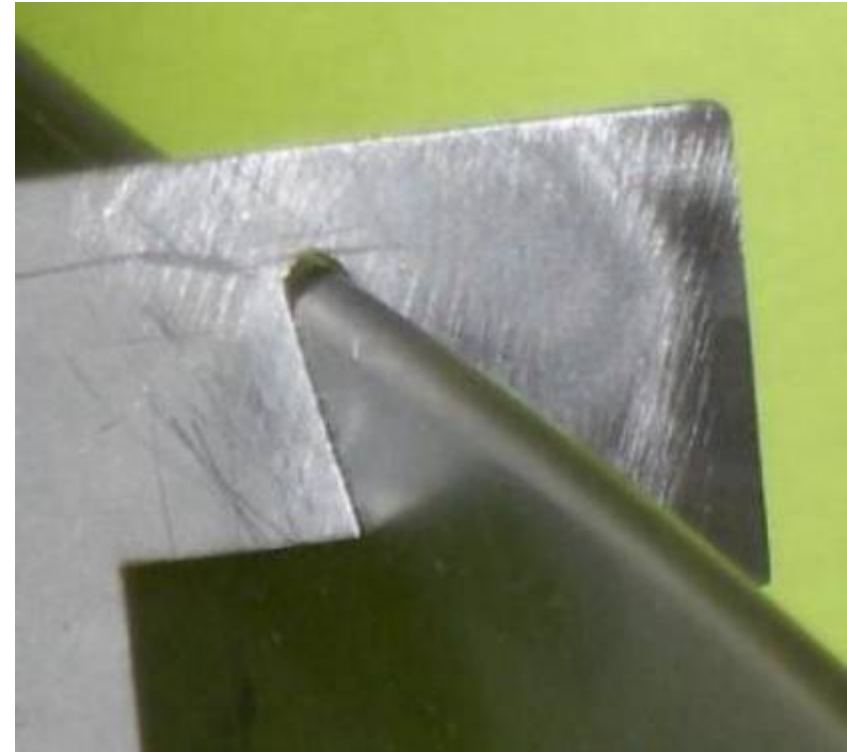
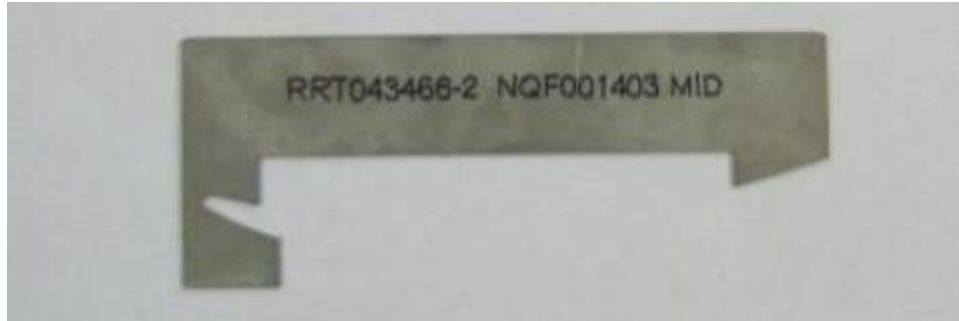
How do we measure them today?

- **Mk 1 eyeball**
- **Profile projector (direct or indirect)**
- **CMM**
- **Structured light systems**



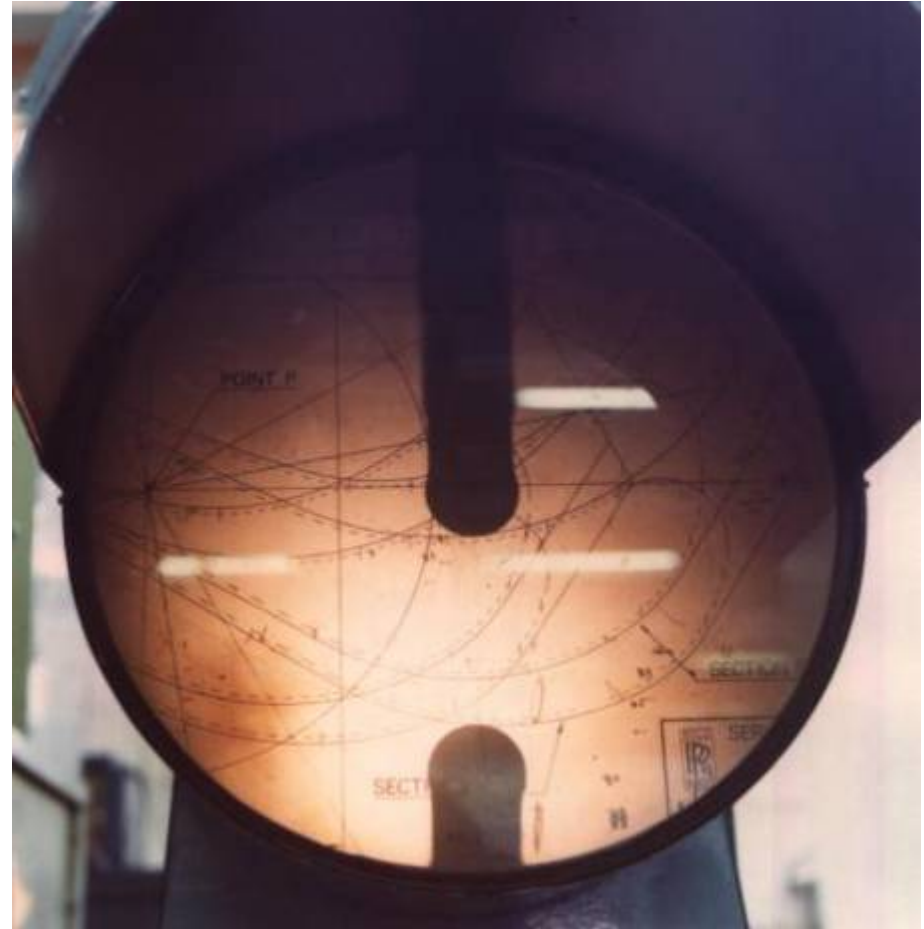
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Form template



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Projector

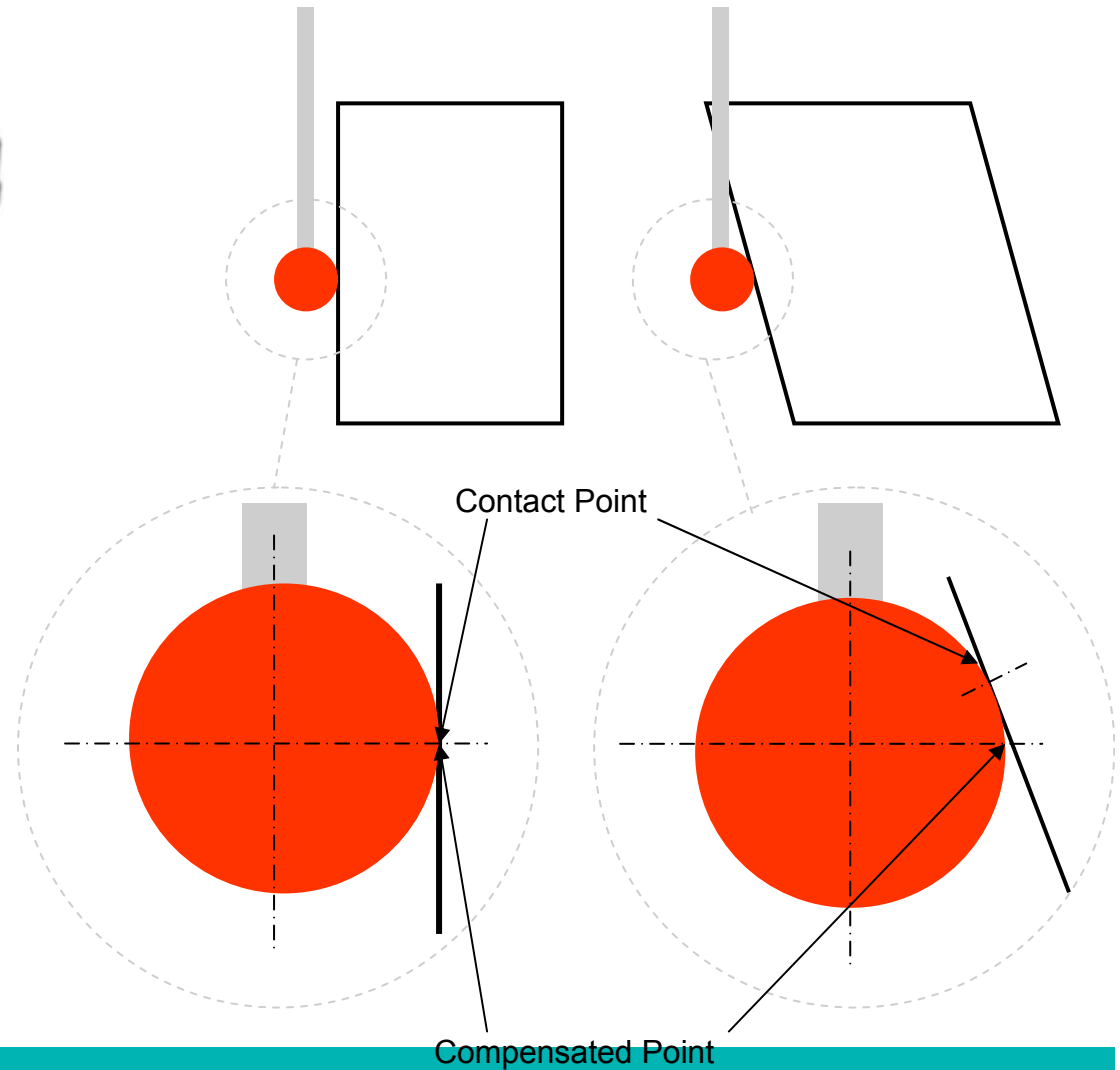


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CMM



- Relatively sparse points on discrete sections
- Datums can have an effect on measured sections (thickness and edge shape)
- Cosine error – multiple scans to compensate

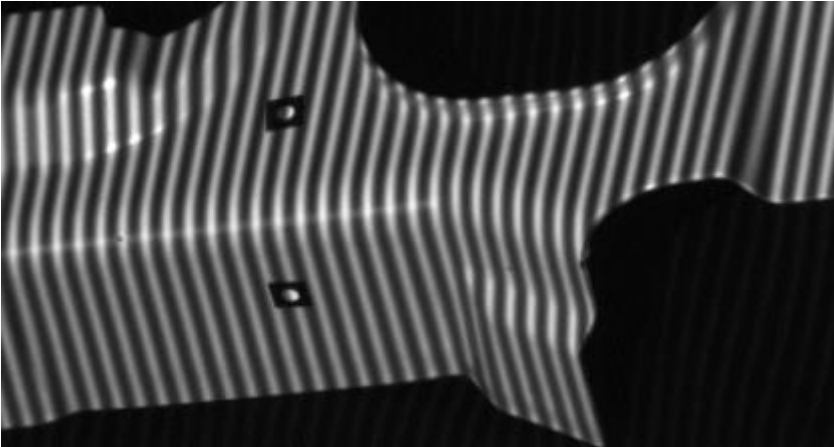
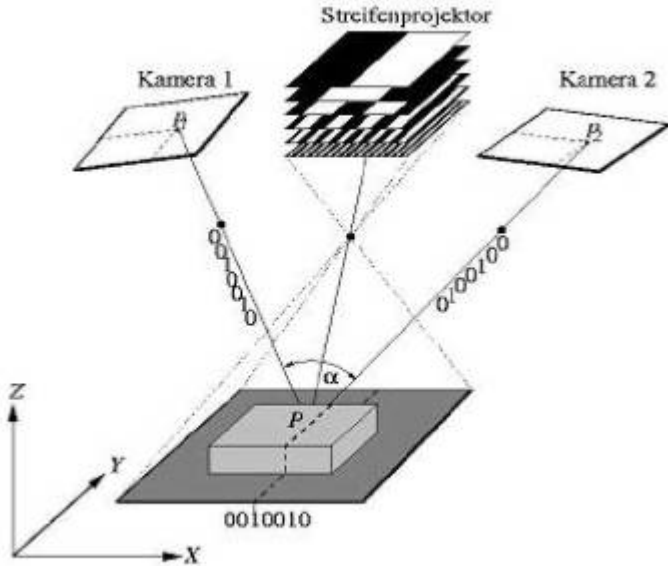


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GOM ATOS System

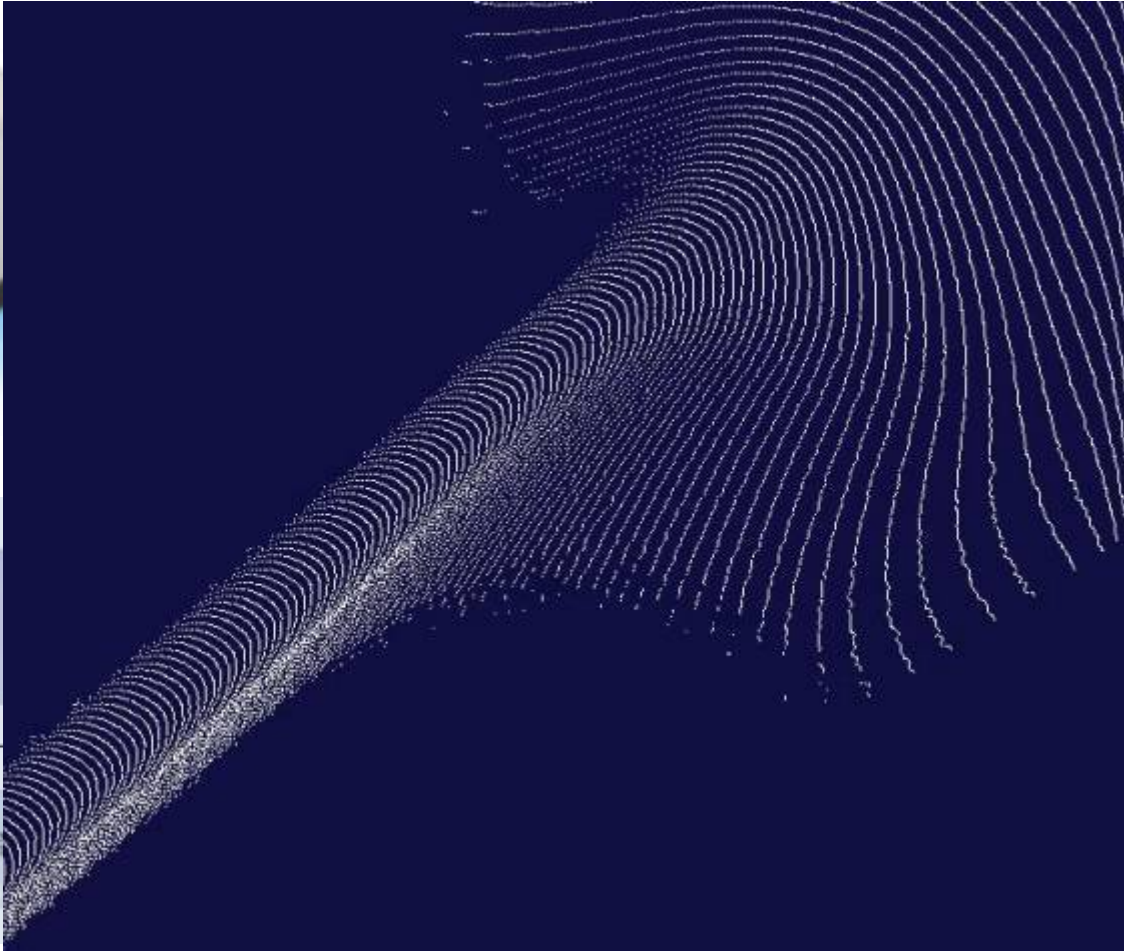
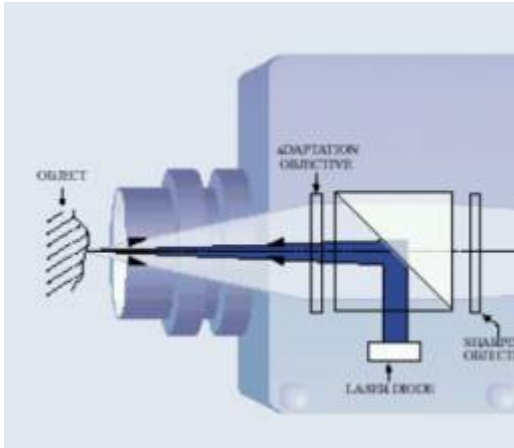


ATOS II system



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Conoscopic Holography



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Non-contact inspection

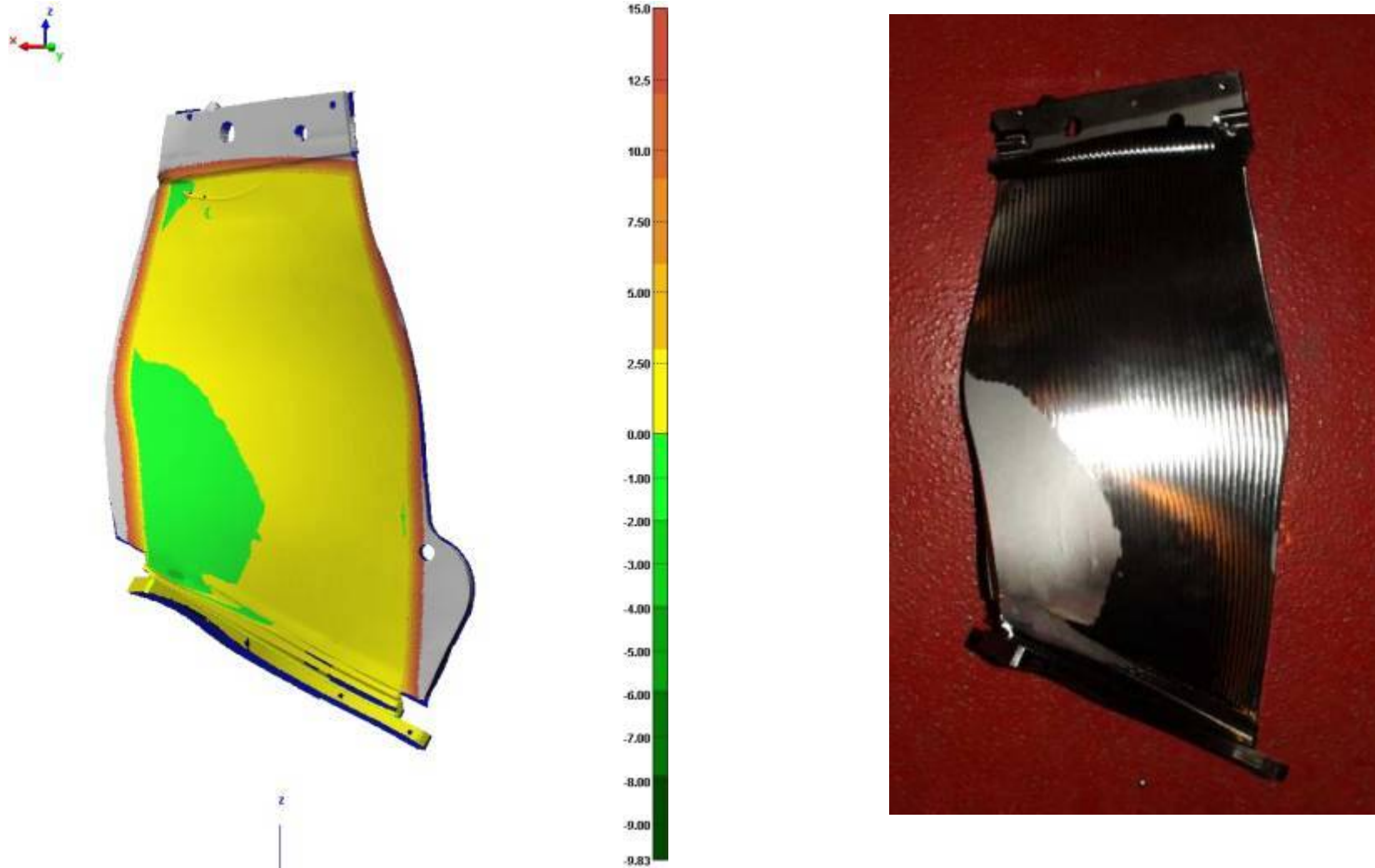
Metris

- PH10 & ACR compatible, using Renishaw Multiwire
- Dimensions - 105 x 60 x 95 mm
- Data capture rate - Approx 19,200 points/sec
- LC50 (DOF), LC100(DOF), LC15(DOF) available soon
- Accuracy +/-29 μ m at 4sigma on optically good, flat plate



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Prediction of Clean-up on Blade



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Renishaw Revo Scanning Probe



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Rapid head touches



Circle scans



Helix scan



Sweep scan



Revo Scanning modes

Gasket scan



Blade sharp edge
sweep scan



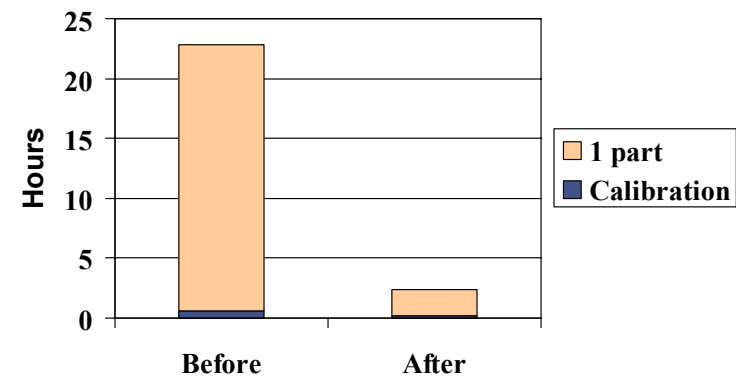
Scan on curve



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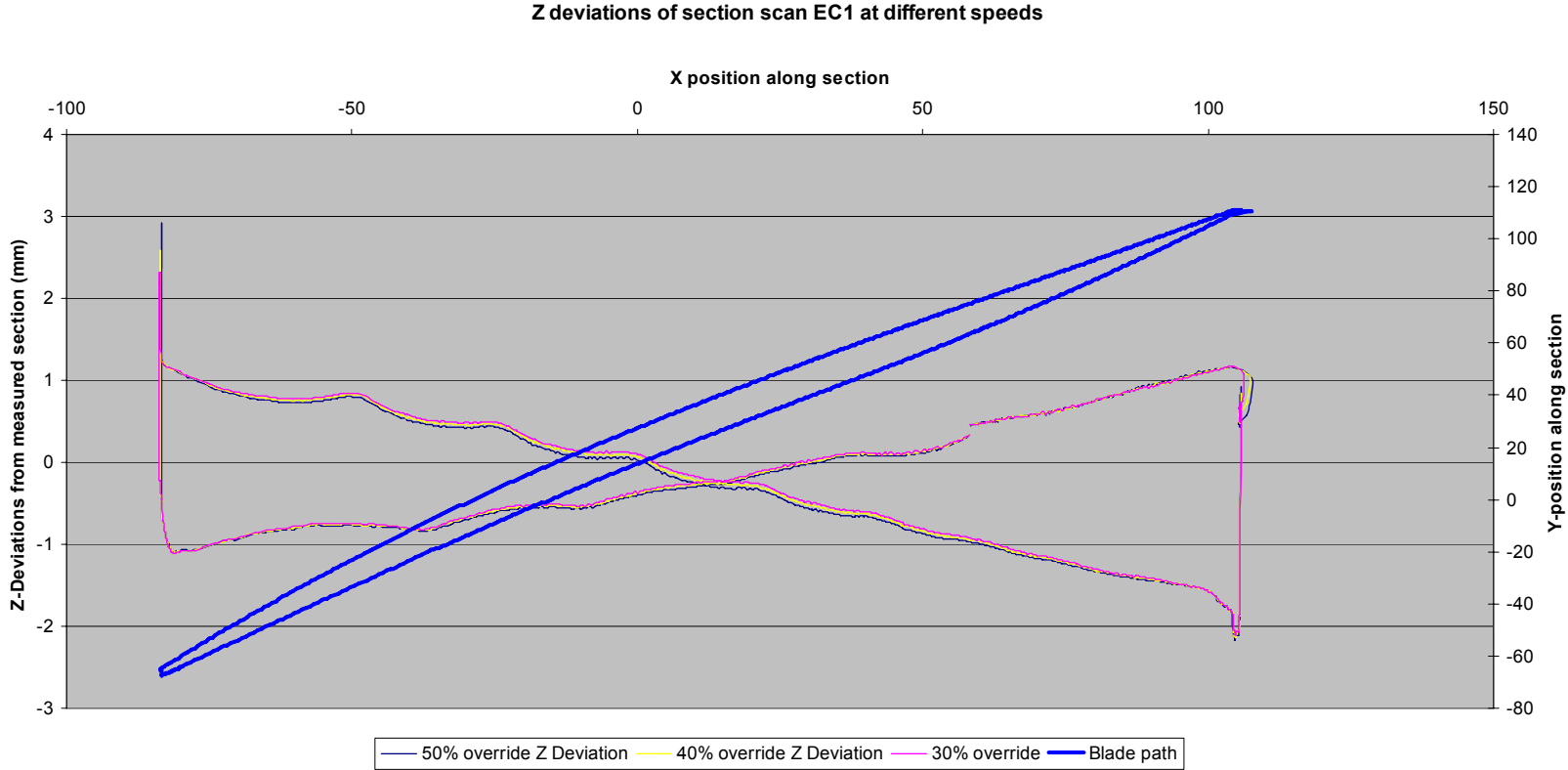
Actual Blisk Measurement Results

- The measurements
 - 9 sectional scans, 8 longitudinal scans, 2 root profile scans, 1 scan of annulus profile
 - Before
 - 3-axis scanning at 10 mm/sec
 - 1 blade – 46 min, all 29 blades – 22 hours 14 min
 - After
 - REVO™ at 200 mm/sec
 - 1 blade – 4 min 30 sec, all 29 blades – 2 hours 11 min
- 922% throughput increase
- Calibration
 - Before: 17 index positions, 33 mins
 - After: 10 mins
- 230% throughput increase



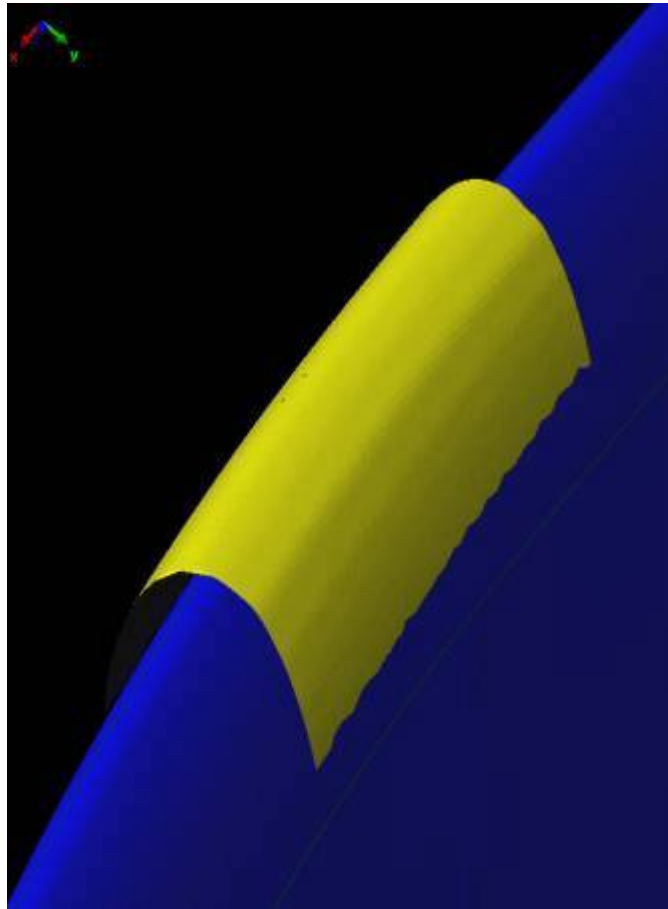
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Out-of-plane Z height error

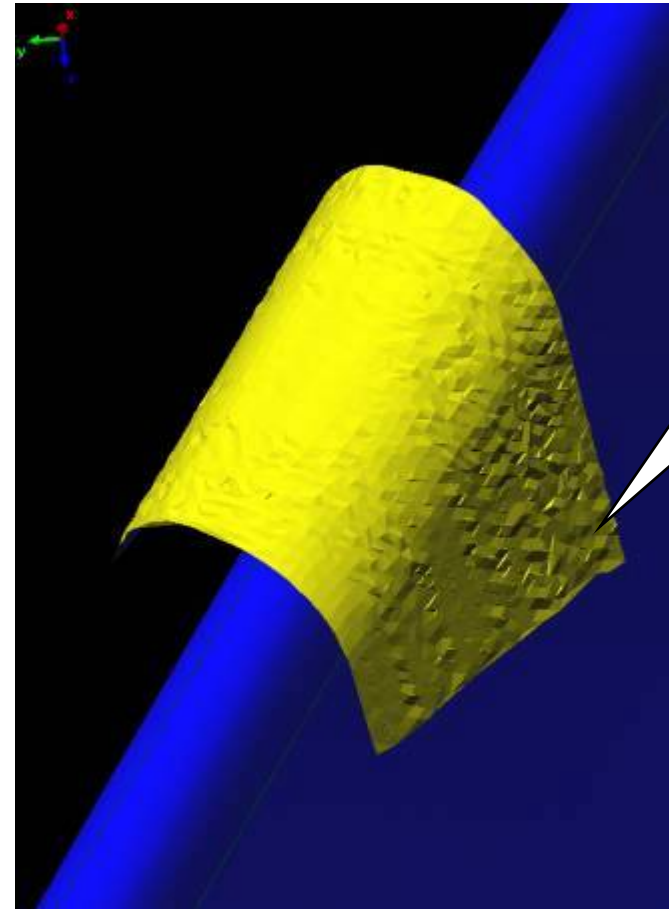


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Accuracy Of Sweep Scan - PolyWorks



LE – Polygonised data in Polyworks



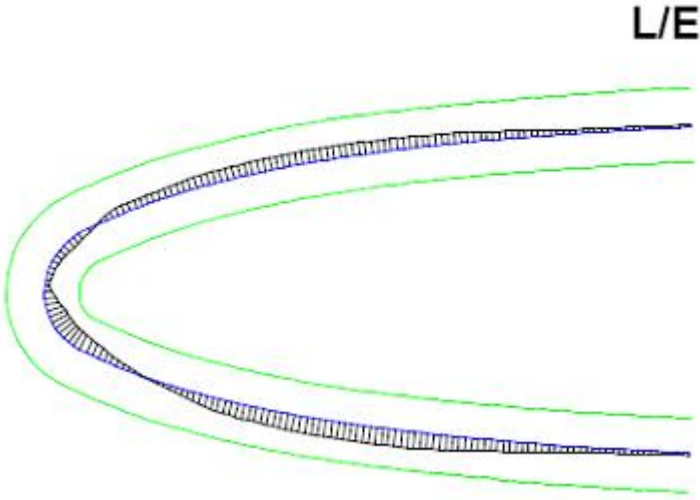
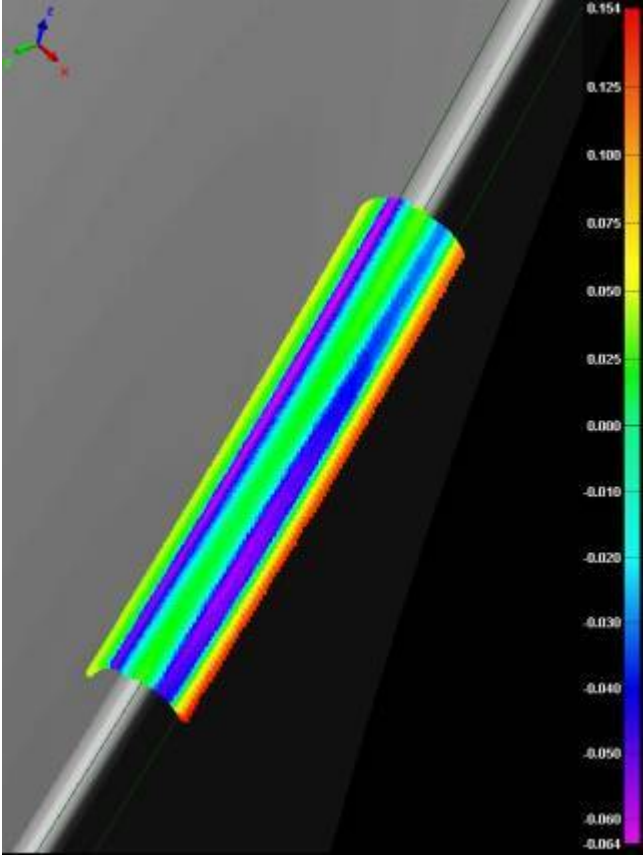
Noise in data resulting from use of small probe... shanking?

TE – challenging head orientation for sweep scanning produces more noise in data



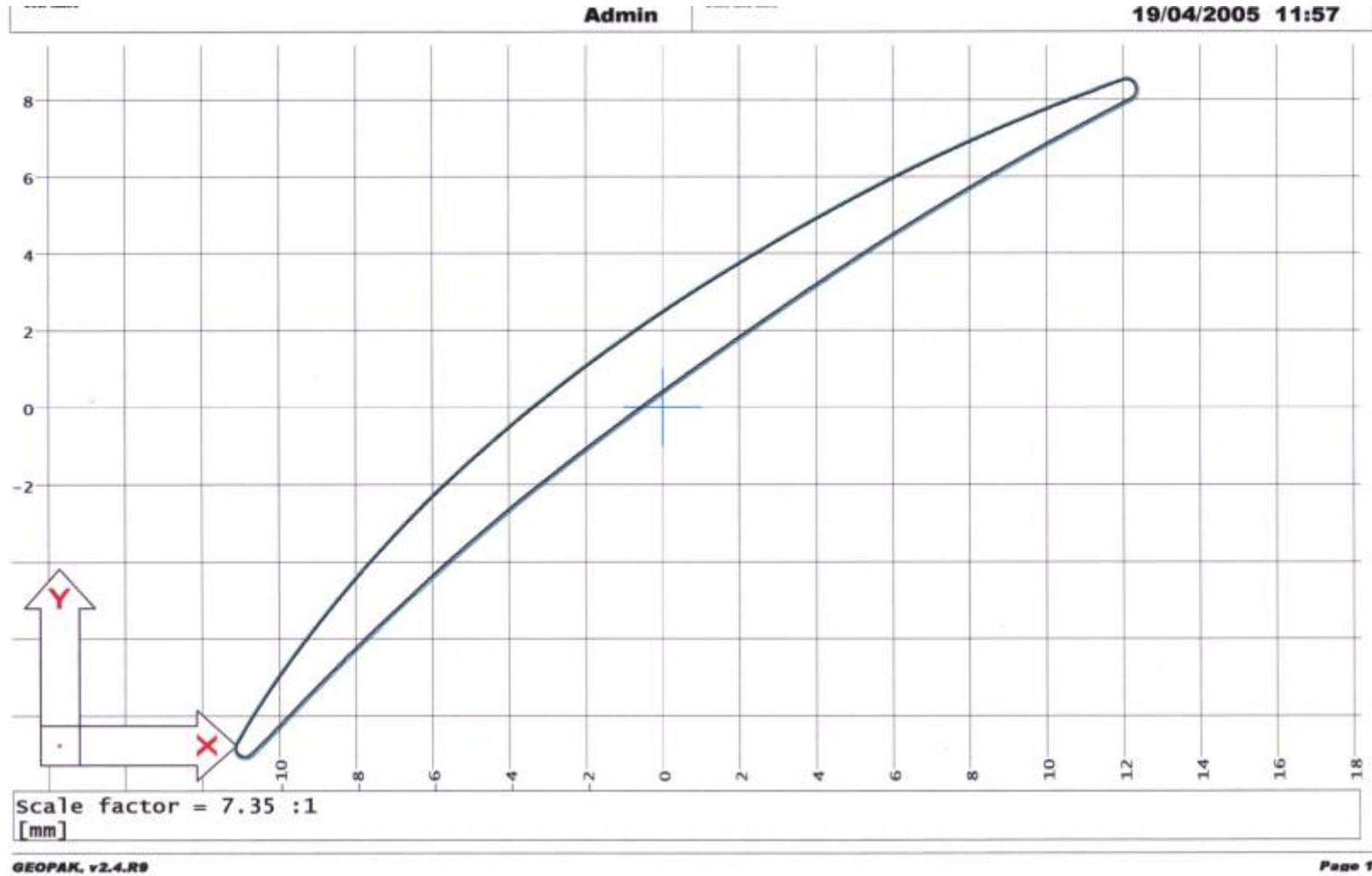
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Comparison of Revo with SP25



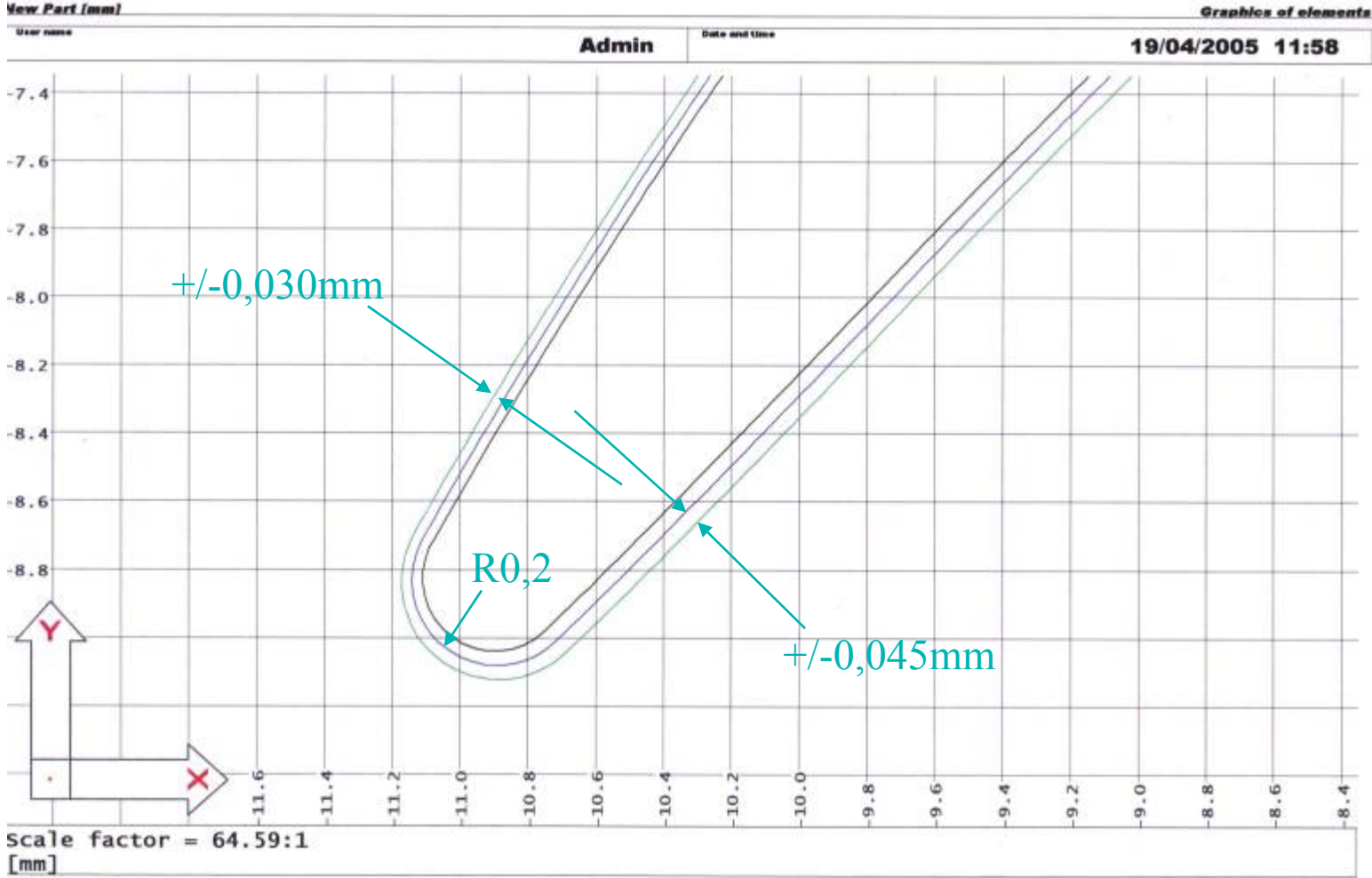
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Compressor blade design – in reality



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Leading edge shape



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Real edge shapes



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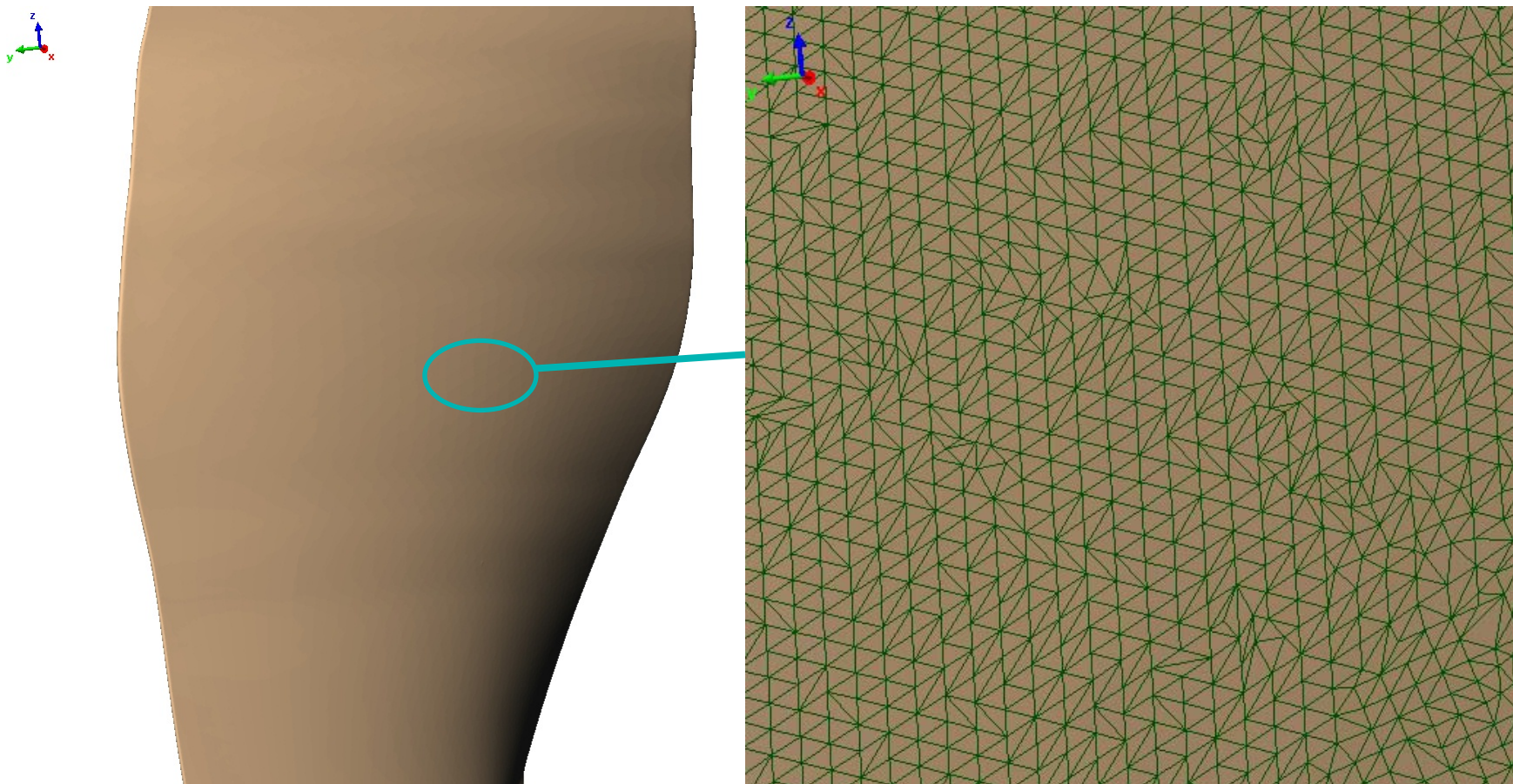
So what's the problem?

- **It's very difficult to create a specific le shape – it's currently a product of process + hand dressing**
- **It's very difficult to measure the edge profile accurately, particularly if it's a blisk**
- **Even if you can measure it, it's very difficult to assess its conformance**



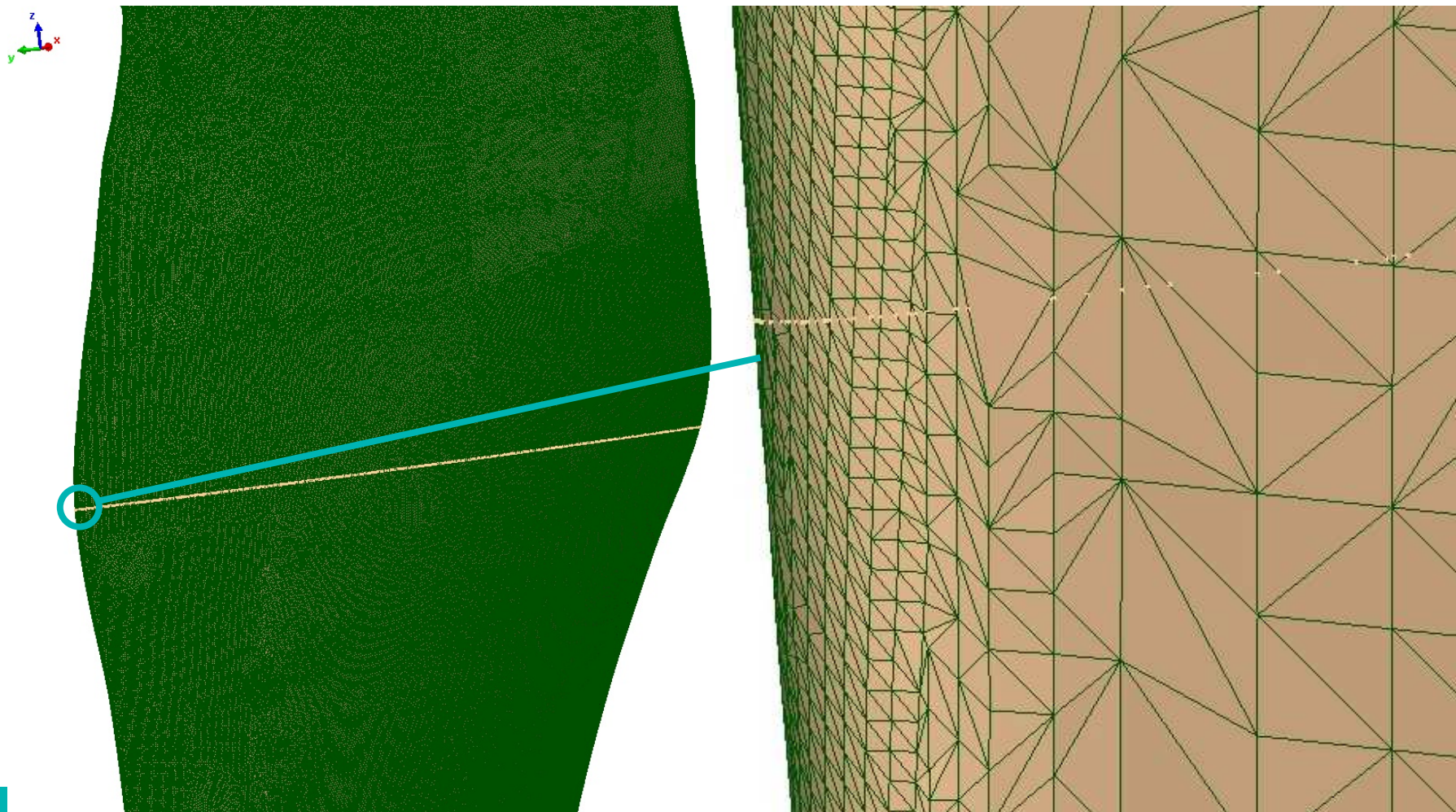
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Polygon mesh



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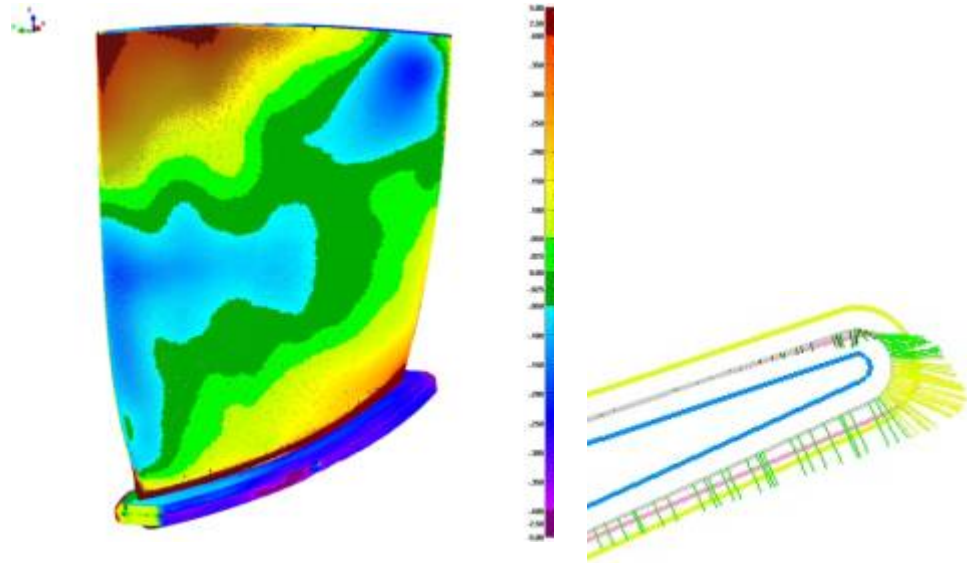
Plane intersection with polygons



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Blade cross-section analysis using Polyworks

- Chord
- Camber
- Stagger
- Displacement
- Thickness
- Gauge Points
- GD&T
- Comparison to 3D CAD definition



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CMM Reference measurement

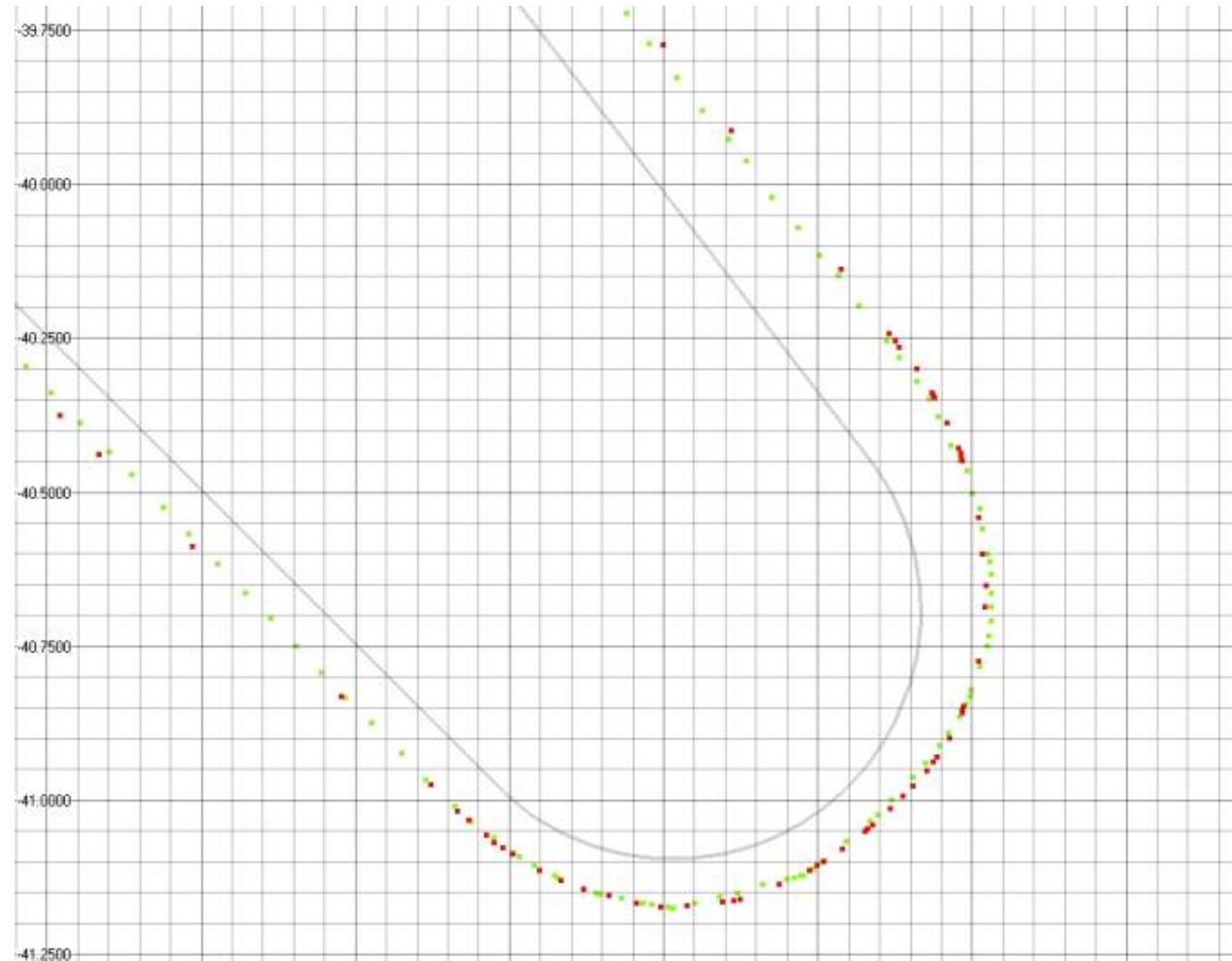


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GOM ATOS III – Optical Digitiser

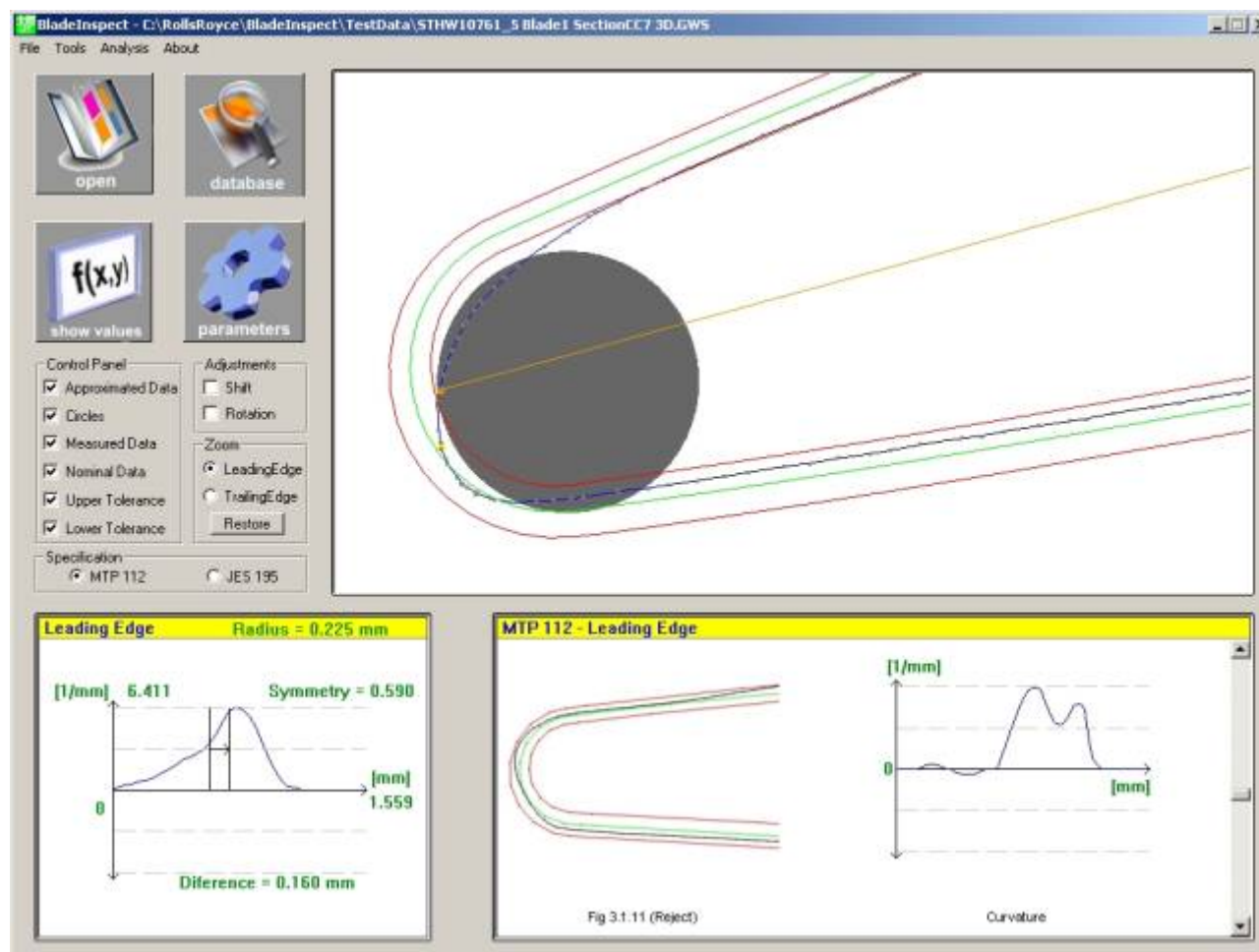
Red = CMM

Green = GOM



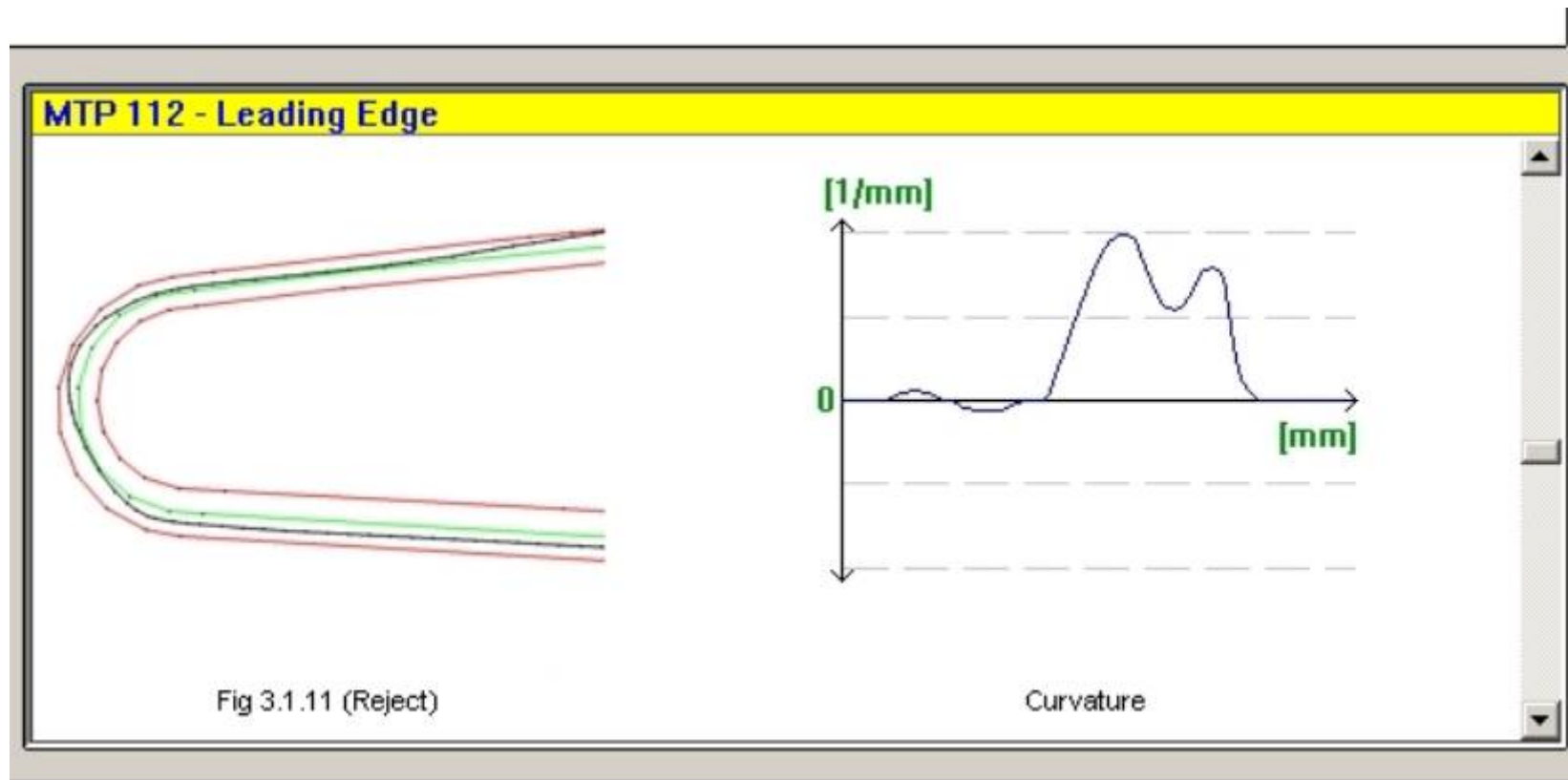
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Automated blade edge assessment



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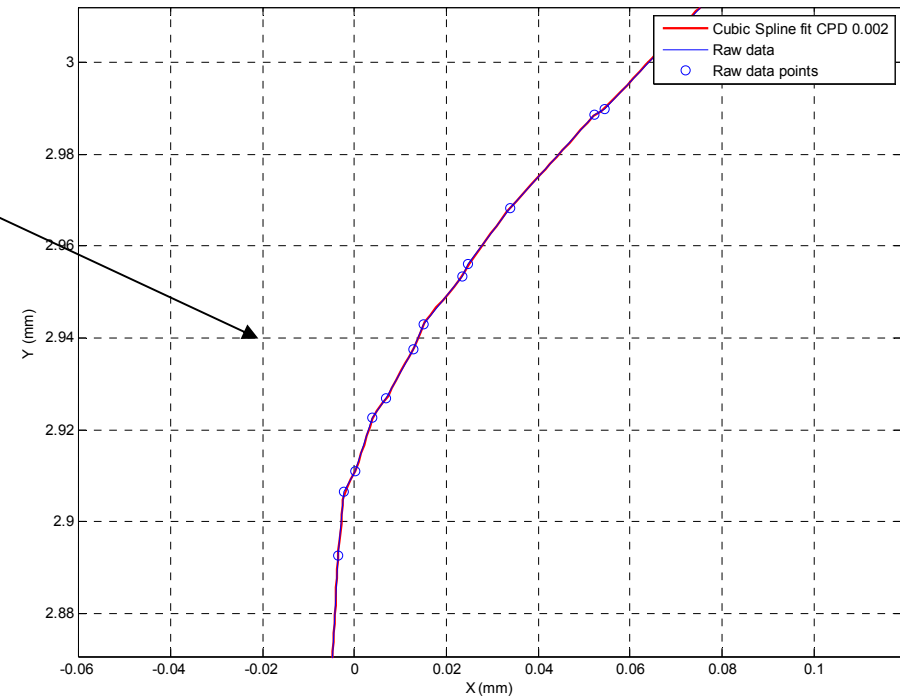
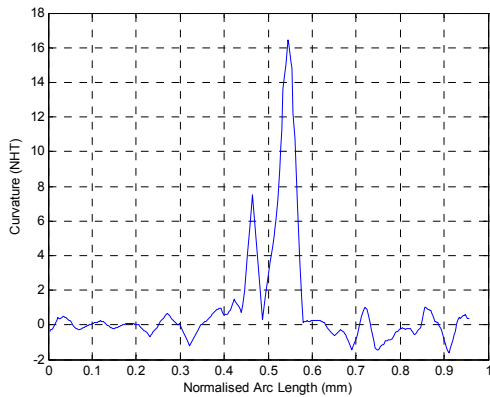
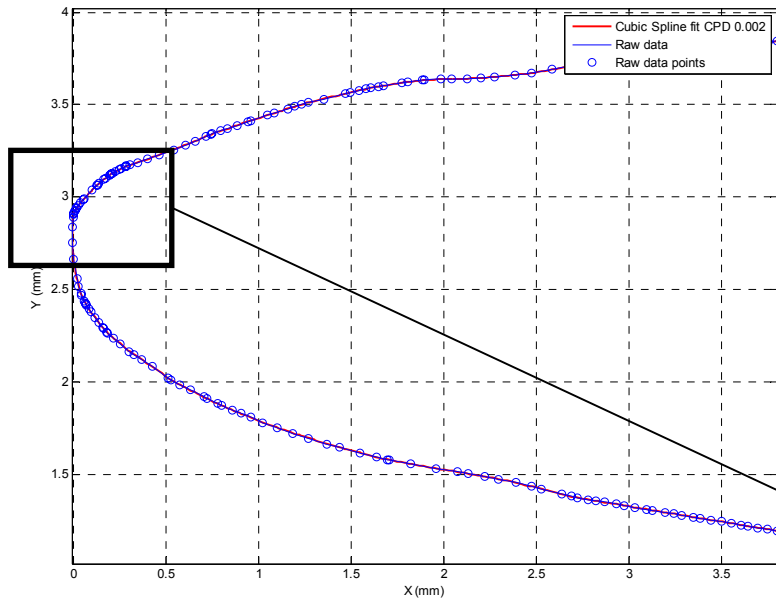
Automated blade edge assessment



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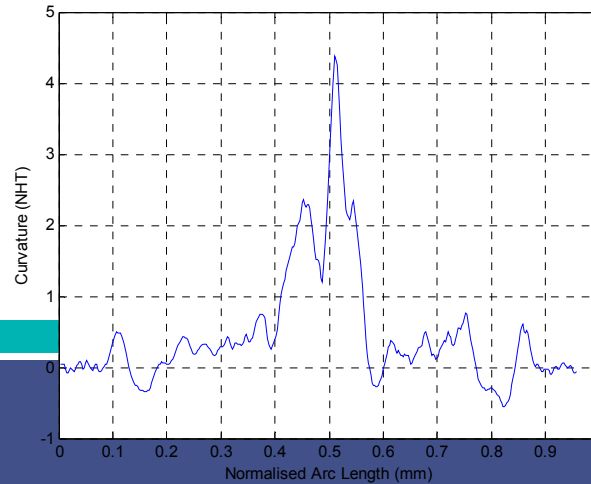
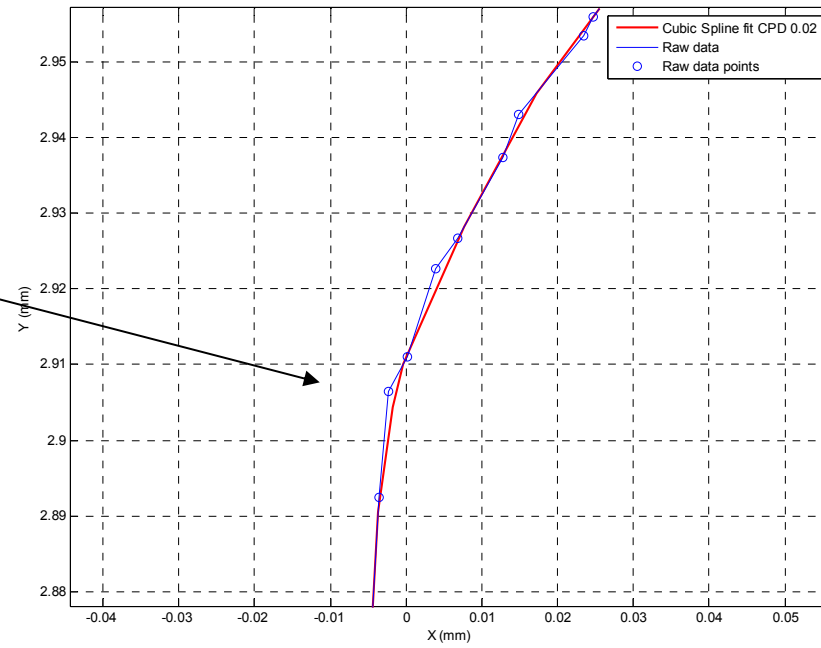
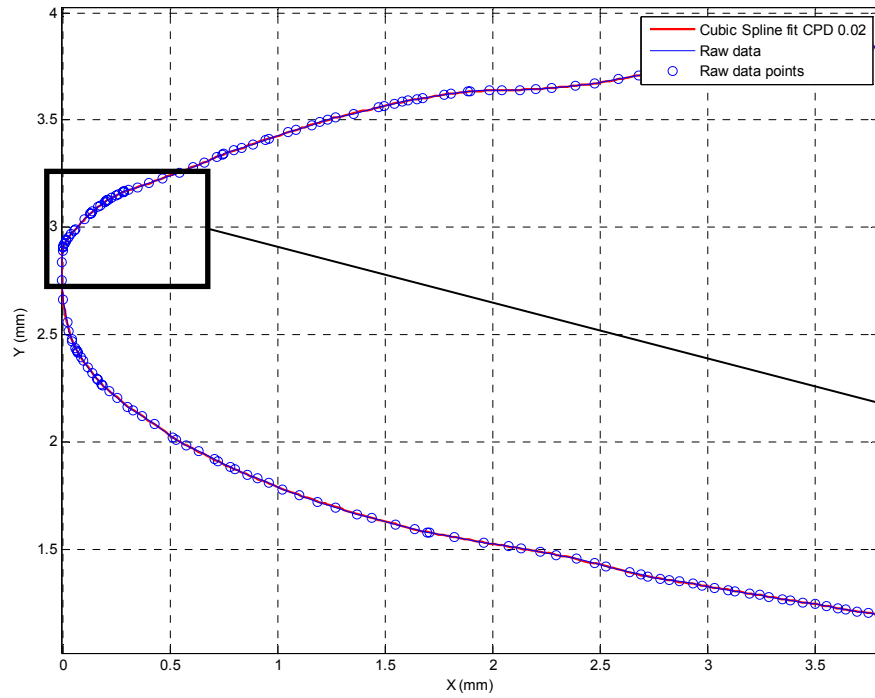
Control Point Distance(CPD) =0.002mm

- 1-Linear interpolation resampling for equidistant point distribution
- 2-Cubic spline fit as a function of CPD along Arc Length



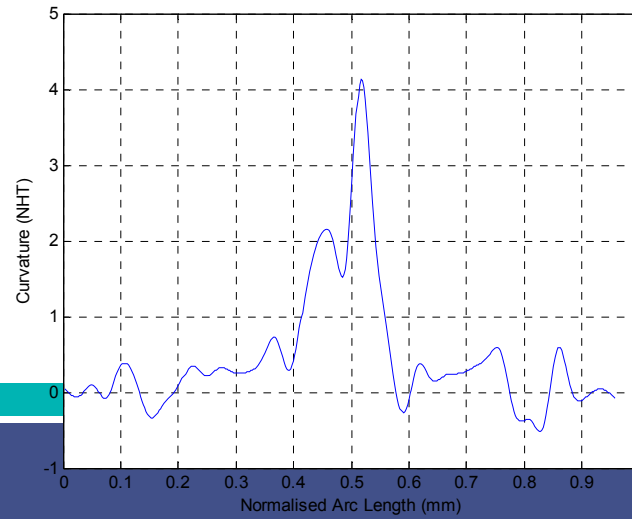
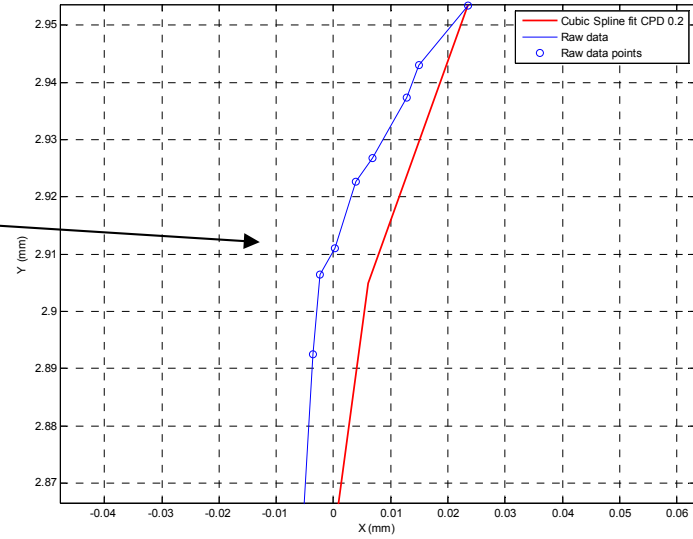
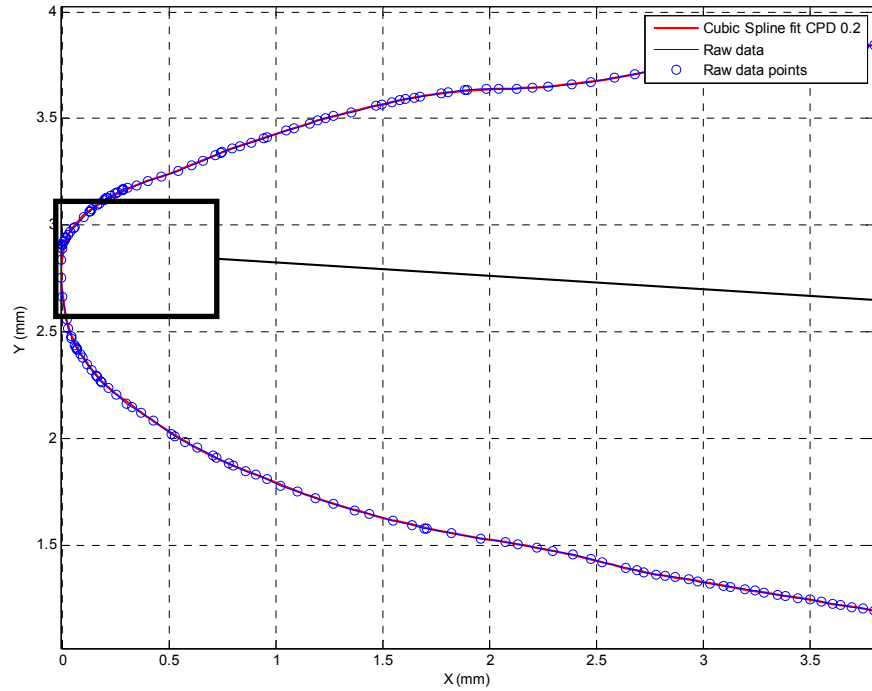
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Control Point Distance(CPD) =0.02mm



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Control Point Distance(CPD) =0.2mm



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Contact v non-contact

- **Non-contact – the good:**
 - **Very high data density**
 - **No ball radius compensation issues**
 - **Easy to set up and program**
 - **Take the measurement system to the job**
- **The bad:**
 - **Accuracy limited – measurement uncertainty?**
 - **May need to coat the object**
 - **Ambient light variation can be a problem**



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Contact v non-contact

- **Contact – the good:**
 - **Very high resolution and accuracy**
 - **Demonstrable measurement uncertainty**
- **The bad:**
 - **Limited data quantity**
 - **Ball radius compensation can be a problem**
 - **Programming can be complex**



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Thank you for your attention.

Any questions?



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