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Methods to assess material loss of the modular taper interface in retrieved hip replacements

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- Introduction
- The taper junction interface
- Method outline
- Taper form
- Measurement of femoral head tapers
- Discussion

MailOnline

Poisonous hip implants 'putting thousands of British patients at risk' as medical watchdog launches investigation

The New York Times

F.D.A. Plans a New Review of Metal-on-Metal Hip Implants



Metal hip patients to be monitored



Fears Over Hip Replacement 'Poisoning'



Herald Sun
Stories start here.

Australians hit by hip replacement recall

nzherald.co.nz

Recall sparks hunt for hip patients



Dispatches: The Truth About Going Under The Knife

theguardian

Metal scare over hip replacement joints



HEBDEN BRIDGE
TIMES

'Toxic' hip replacement fears

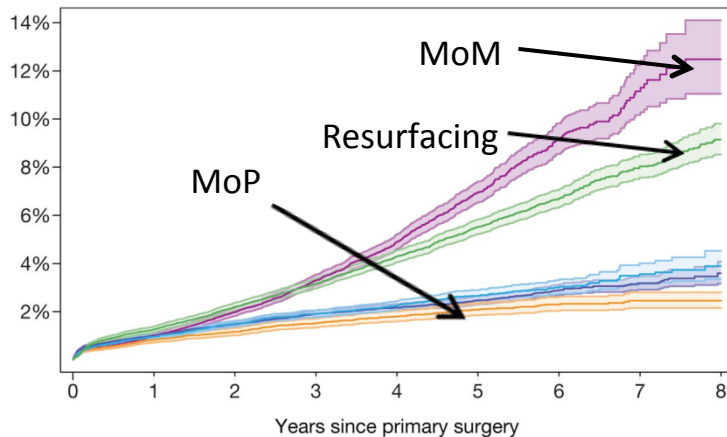
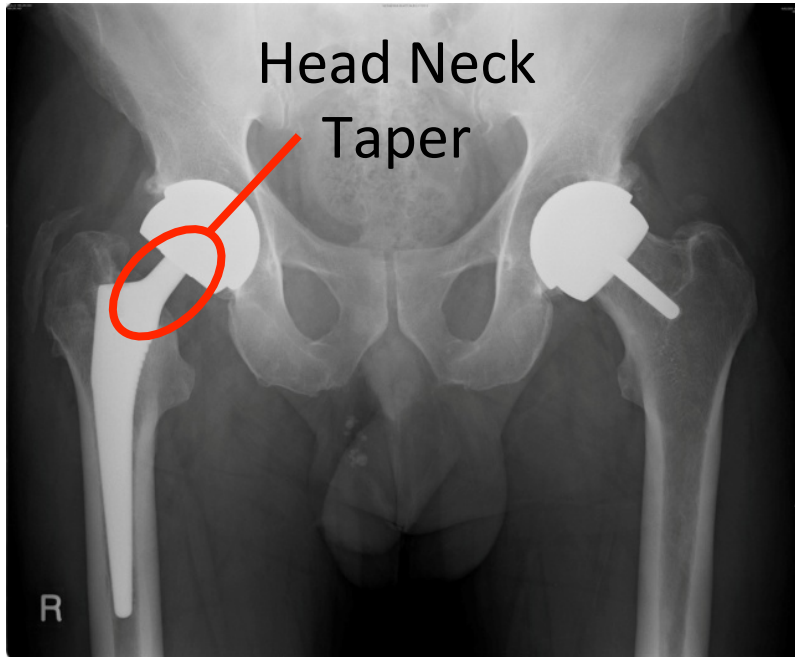
ASTM Symposium on Metal-On-Metal Total Hip Replacement Devices, Phoenix, 08 May 2012

- **>750,000 MoM in US.**
- Bearing surface measurement important.
- Currently no consensus on procedure, strategy etc.
- Need for further development of standards and standardised practices.



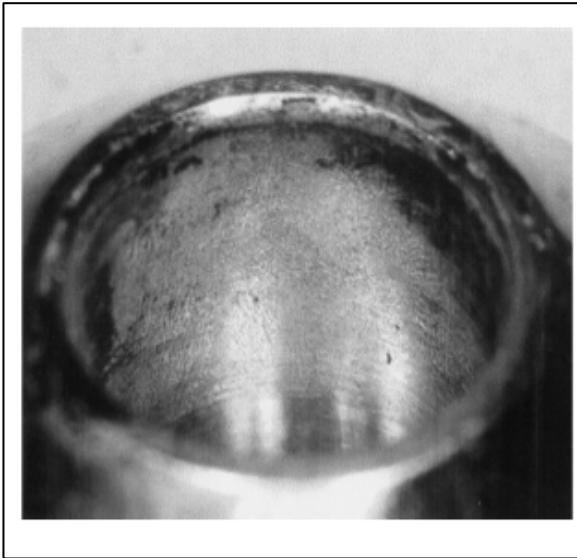
Standards Worldwide - Home





NJR, 9th Annual Report, 2012

- 31,171 modular MoM implanted in UK 2003-2011 [Smith et al 2012].
- 29% failure in some LHMOM at 6 years [NJR 2011].



Goldberg et al, 2002



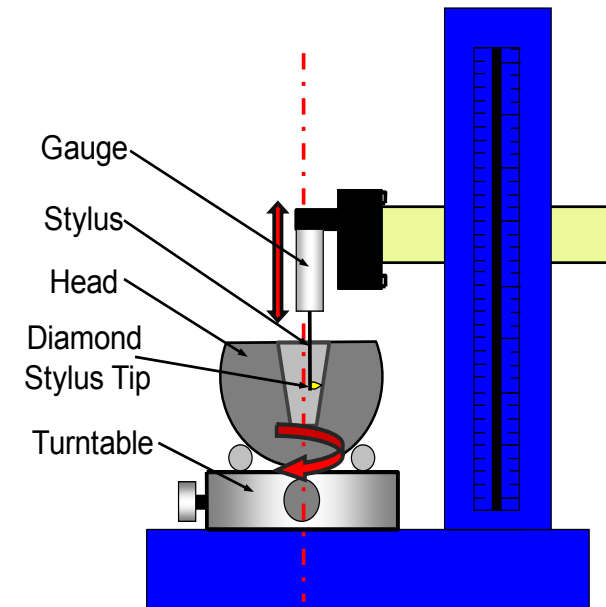
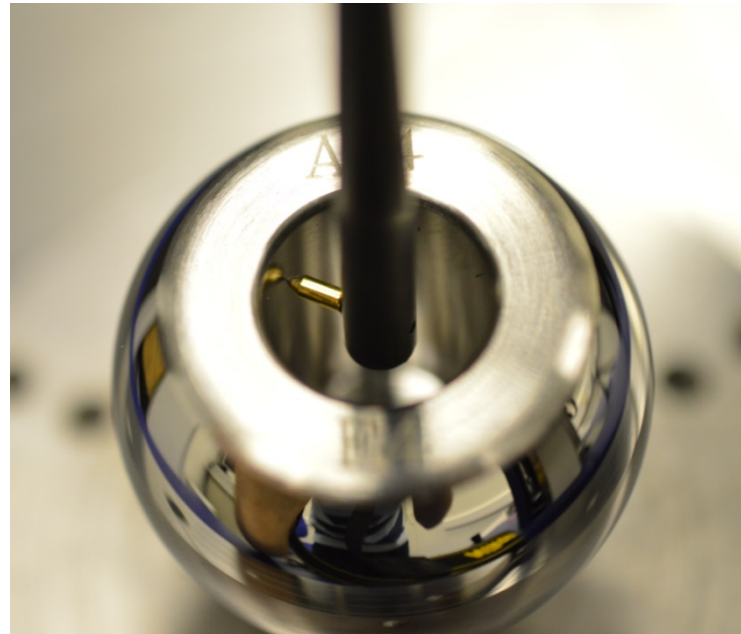
Langton et al, 2012

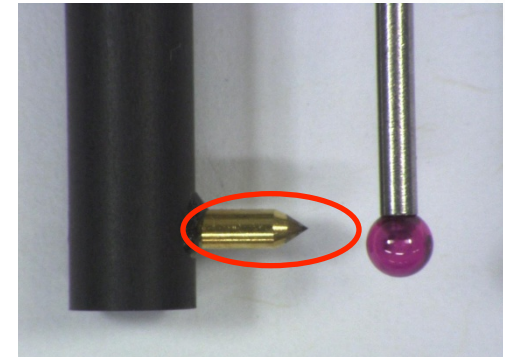
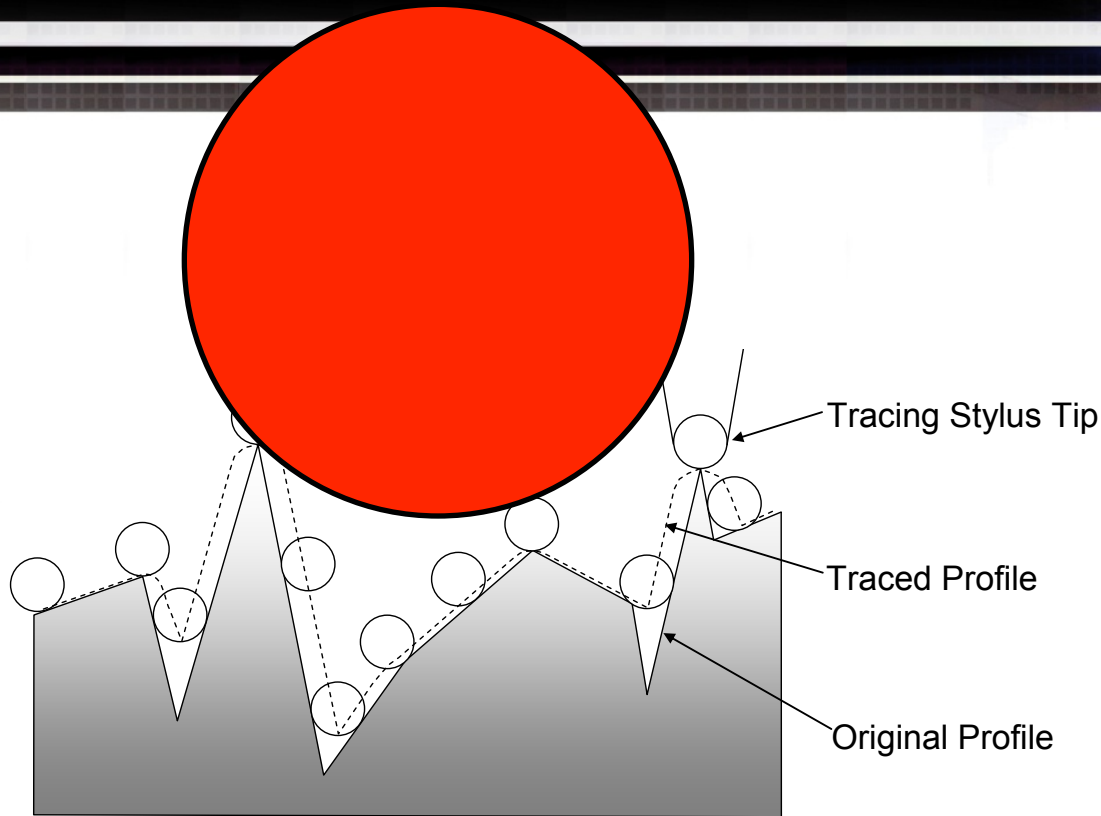


Matthies et al, 2012

- Clear delineation of wear
- “Imprint” of stem taper texture onto female taper.

- Taylor Hobson Talyrond 365 Roundness Machine
- Head/stem mounted on a rotating table, stylus measures deviations in profile.
- Vertical straightness profiles and construction of cylinder maps.
- Gauge resolution 30 nm, spindle run out 20 nm.





Talyrond
Diamond
Stylus

CMM
Ruby
Ball

- Talyrond uses 5 μm diamond stylus, CMM typically 1 mm ruby or bigger.
- Ability to accurately measure texture/structure determined by size of stylus.
- Small stylus allows for fine texture to be recorded.

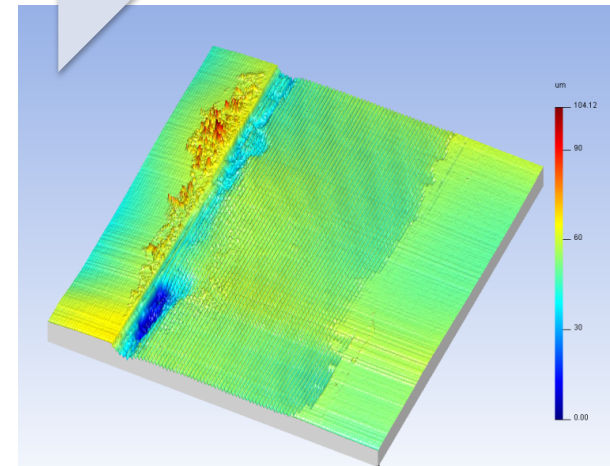
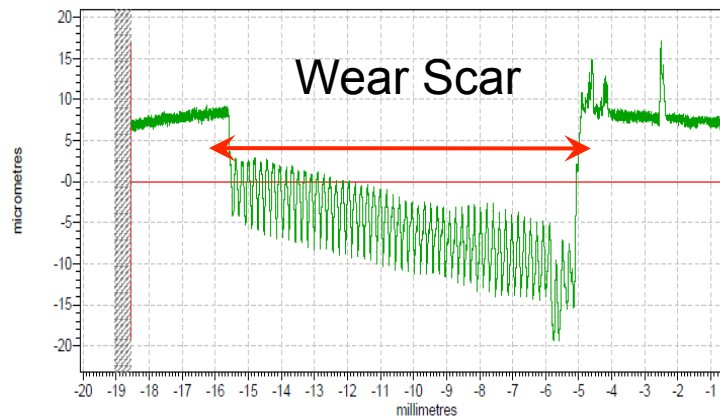
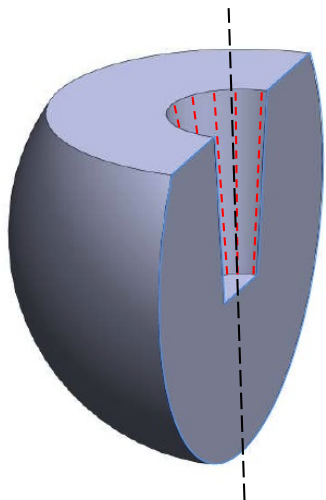
Vertical trace
measurement

Two stage
form removal

Identification
of worn
regions

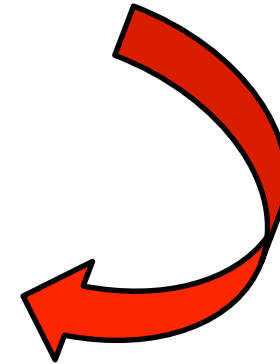
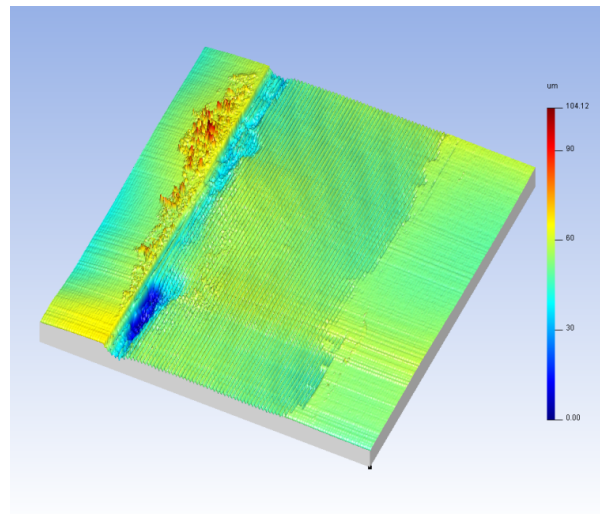
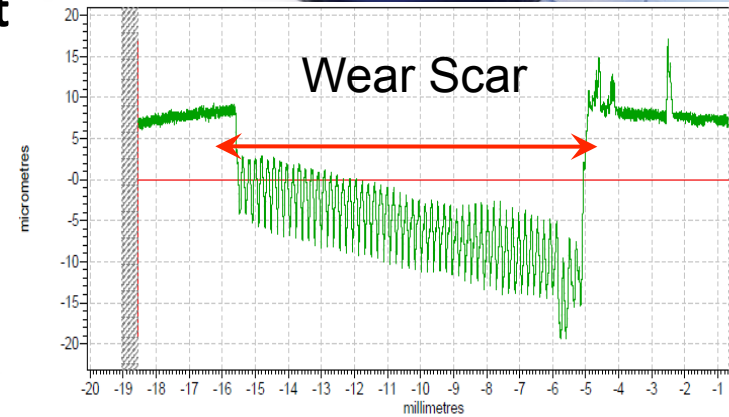
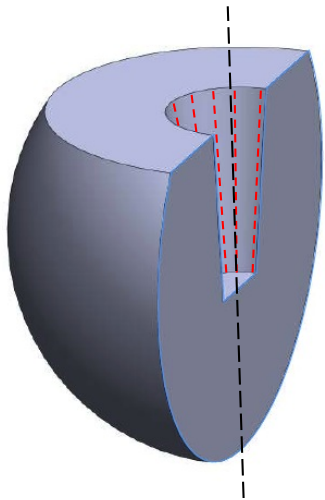
Removal of
debris

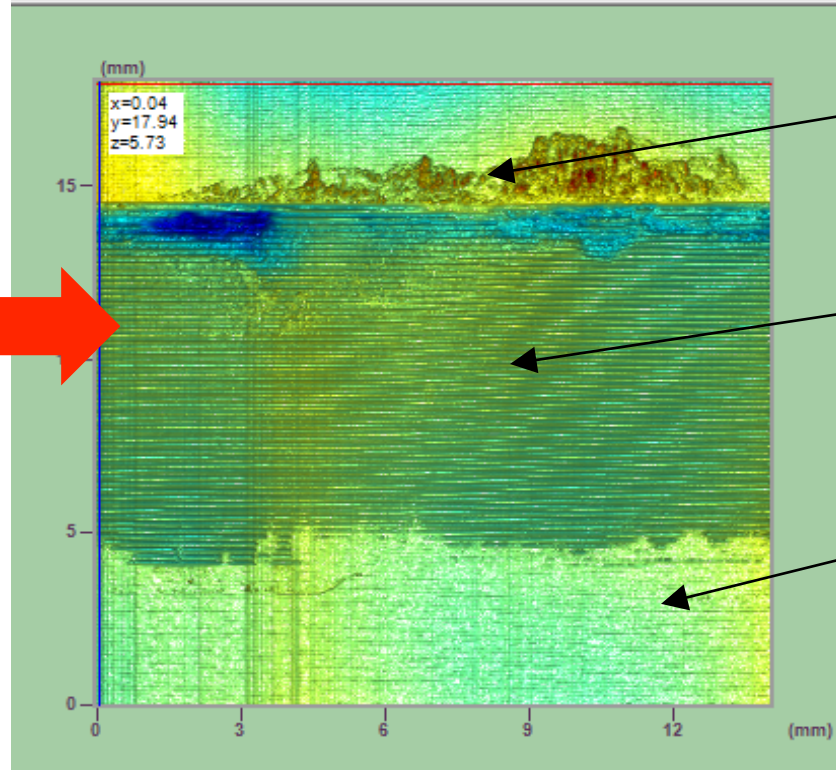
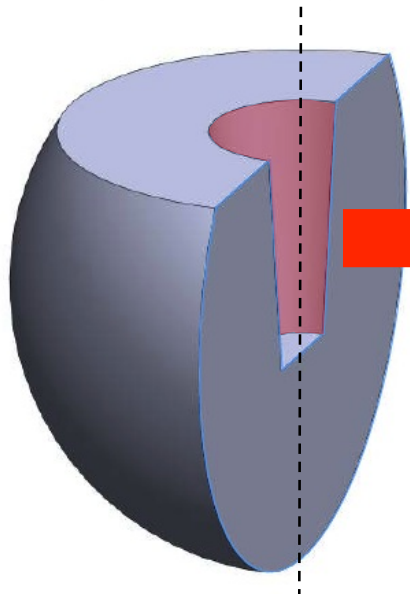
Material loss
calculation



Vertical Straightness Measurement

- › Vertical plots along taper
- › Two-stage form removal
- › Plot “rolled out” to map
- › Identification of worn regions
- › Removal of debris





Deposits at
top of taper

'Worn' region

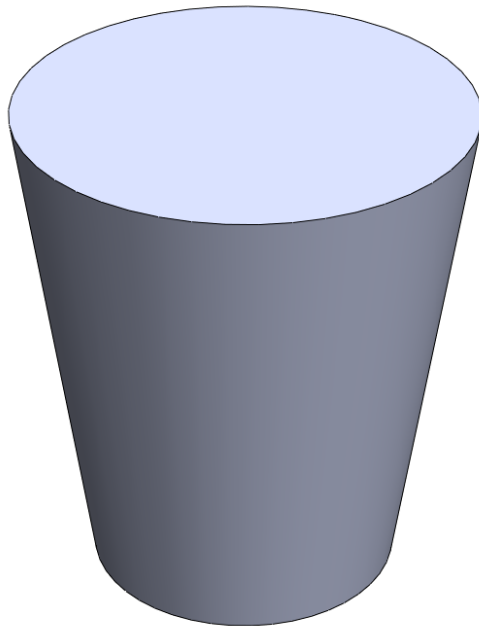
'Unworn' region
at base of taper

360 vertical profiles, angular spacing of 1° ,

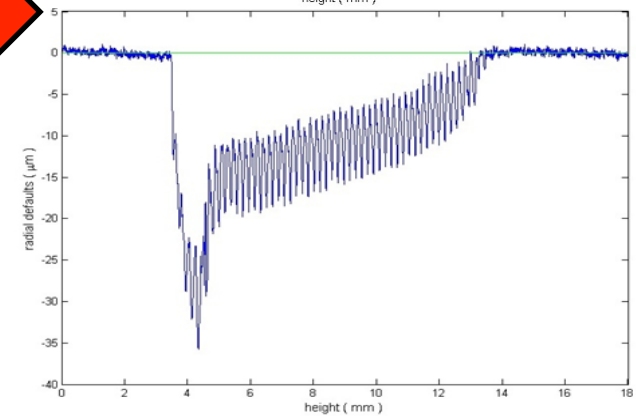
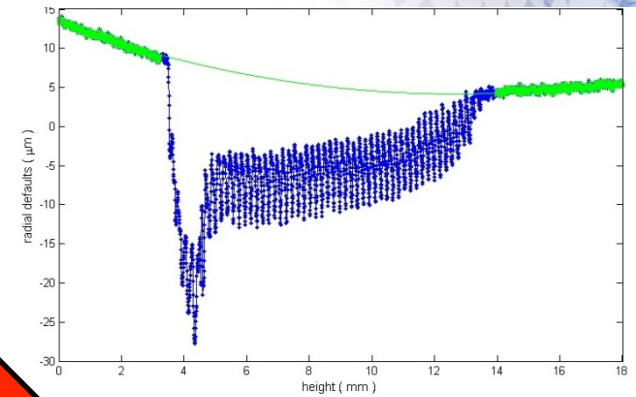
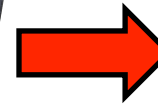
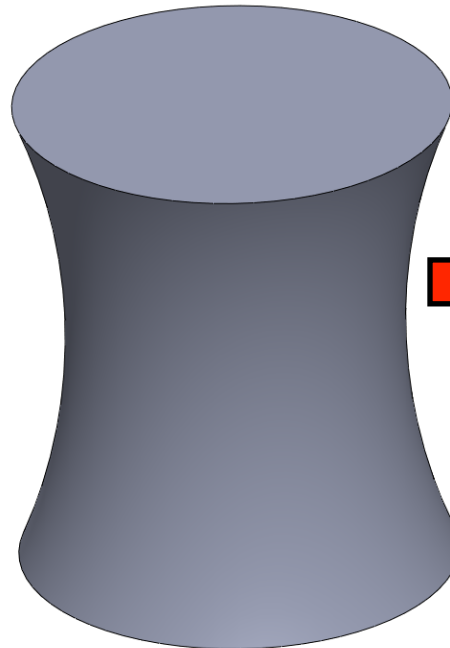
Each profile 7000 points with spacing $2 \mu\text{m}$

Total number of data points 2.5 million

Primary: conic

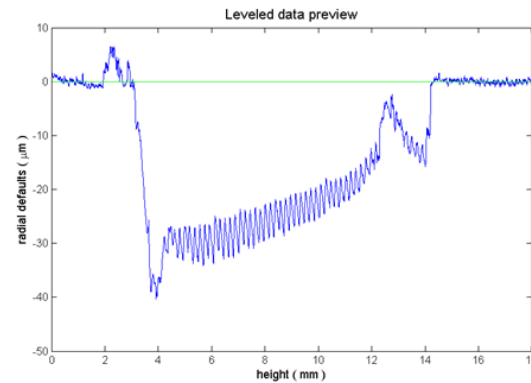
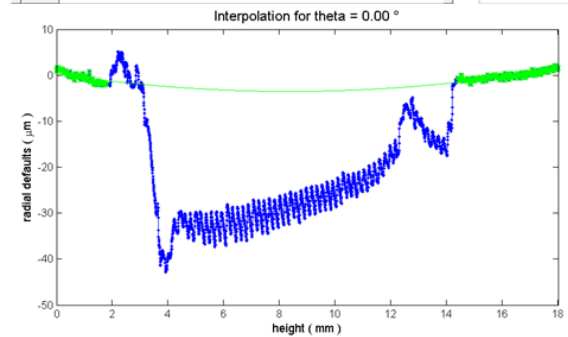
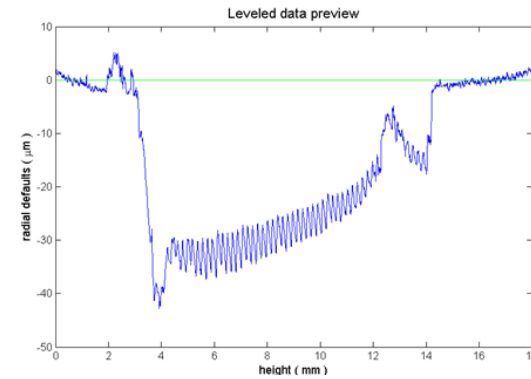
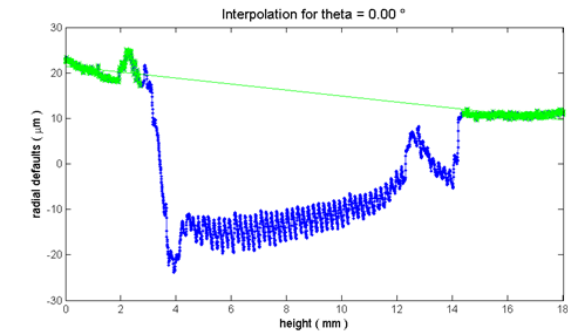
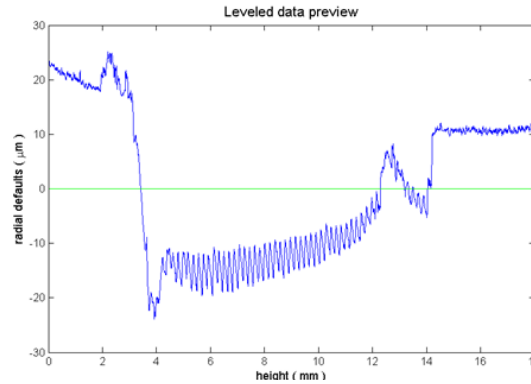
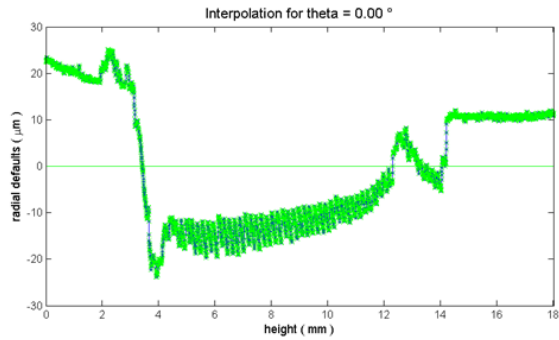


Secondary: quadratic



Two stage form removal process \sim 35% of female tapers had secondary form component (quadratic)

Can give fitting error of up to $5\mu\text{m}$



Average fitting
Material loss: 13.69 mm³

Linear fitting
Material loss 12.36 mm³

Parabolic fitting
Material loss 10.76 mm³

➤ Conical form → Cylindrical coordinates

General expression of a volume :

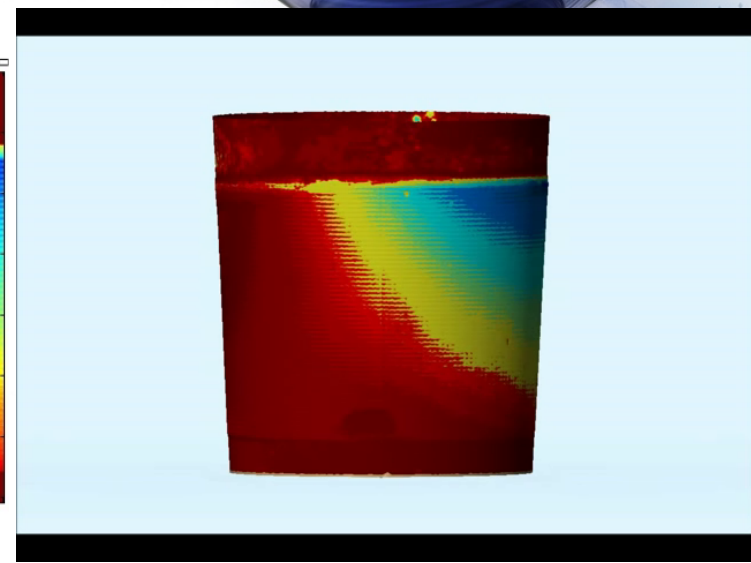
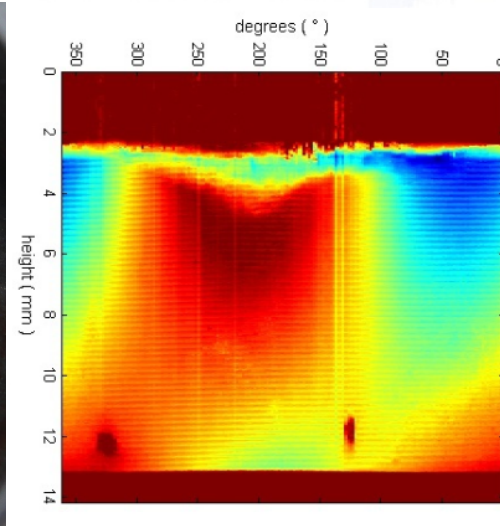
$$V = \int_{\theta=0}^{2\pi} \int_{z=0}^h \int_{r=0}^{r(z,\theta)} dr (rd\theta) dz = \int_{\theta=0}^{2\pi} \int_{z=0}^h \frac{r^2(z,\theta)}{2} dz d\theta$$

➤ Application :

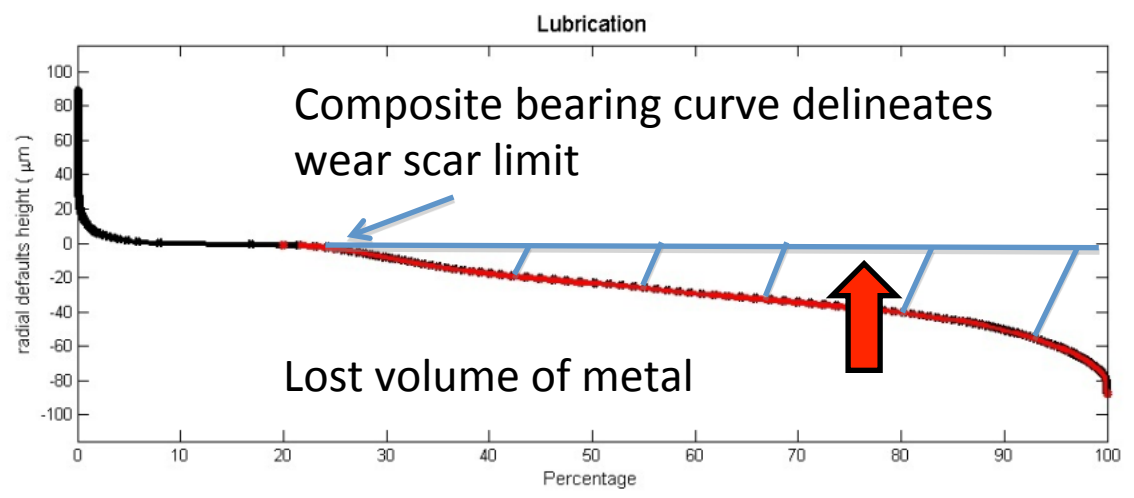
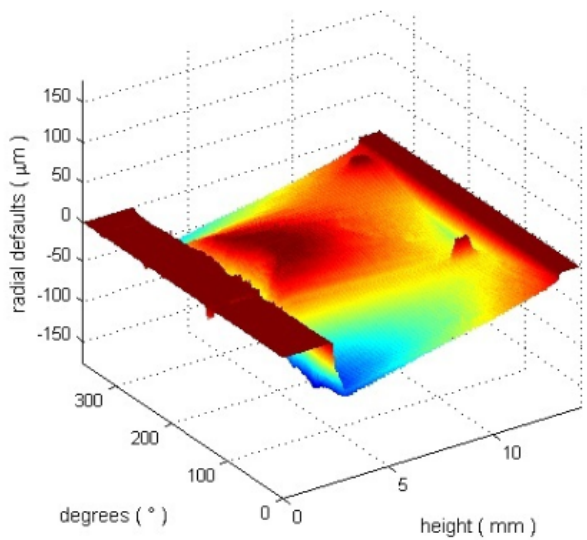
$$\begin{cases} V_{max} = \frac{1}{2} \int_{\theta=0}^{2\pi} \int_{z=0}^h (R_{moy}(z,\theta) + h_{max})^2 dz d\theta \\ V = \frac{1}{2} \int_{\theta=0}^{2\pi} \int_{z=0}^h (R_{moy}(z,\theta) + \varepsilon_{cut}(z,\theta))^2 dz d\theta \end{cases}$$

$$\& \quad V_{loss} = V_{max} - V$$

$$V_{loss} = \frac{1}{2} \int_{\theta=0}^{2\pi} \int_{z=0}^h \left(2R_{moy}(z,\theta)(h_{max} - \varepsilon_{cut}(z,\theta)) + h_{max}^2 - \varepsilon_{cut}^2(z,\theta) \right) dz d\theta$$

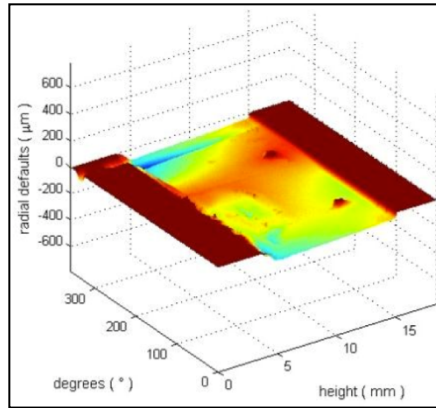


3D Levelled Cone Map

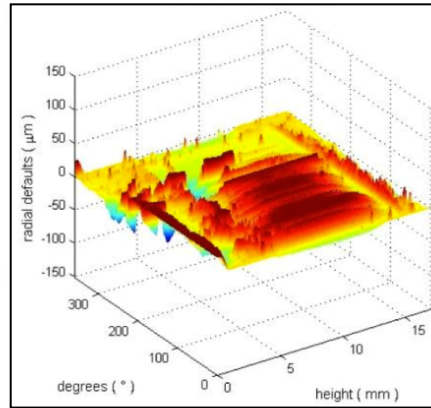


Head Taper Results

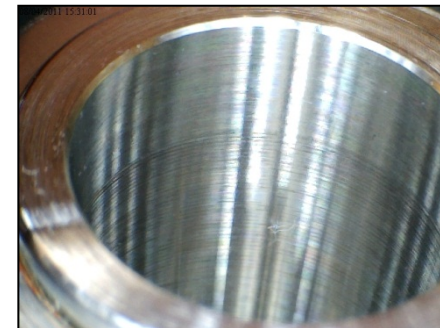
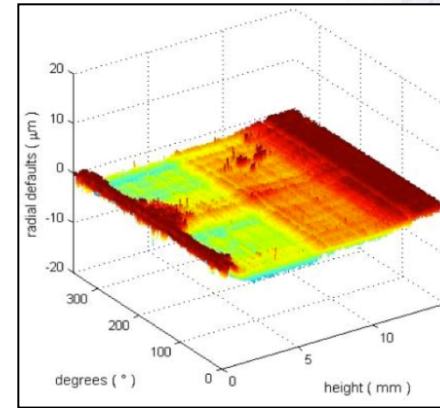
Goldberg vs Quantitative Metrology



Goldberg: 4
Material lost: 25.19mm³

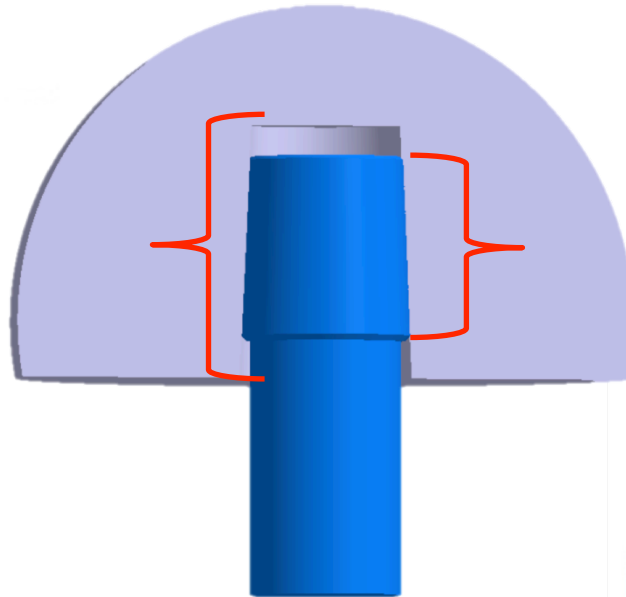
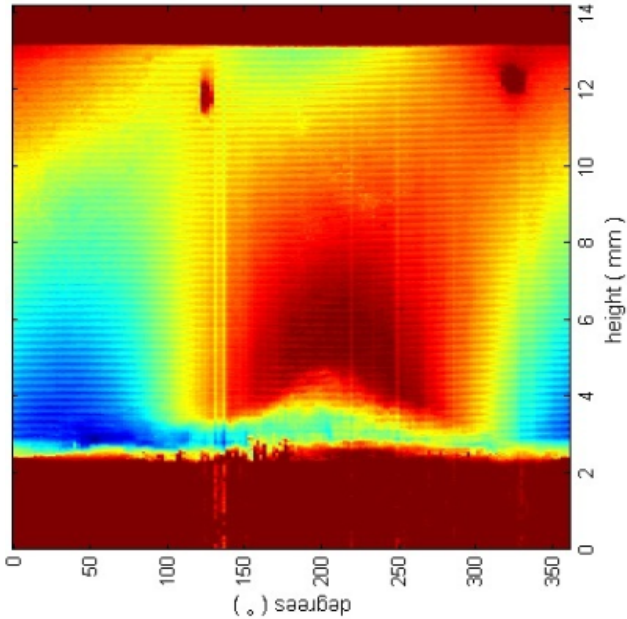


Goldberg : 3
Material lost: 6.21mm³

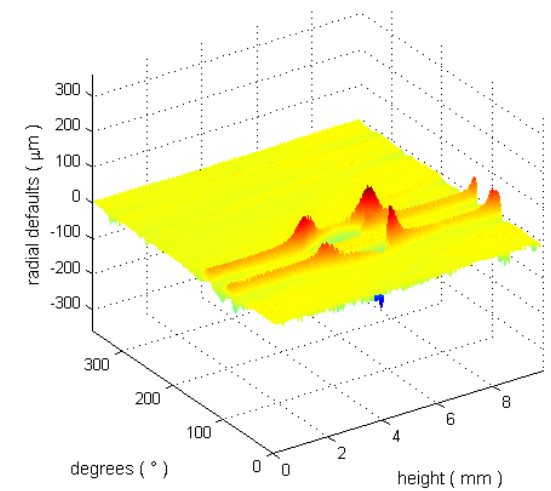
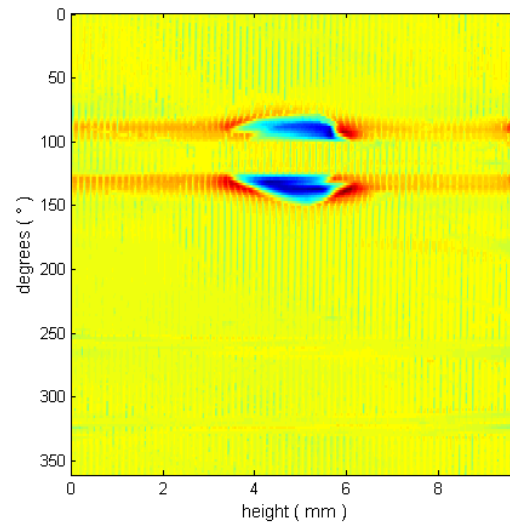
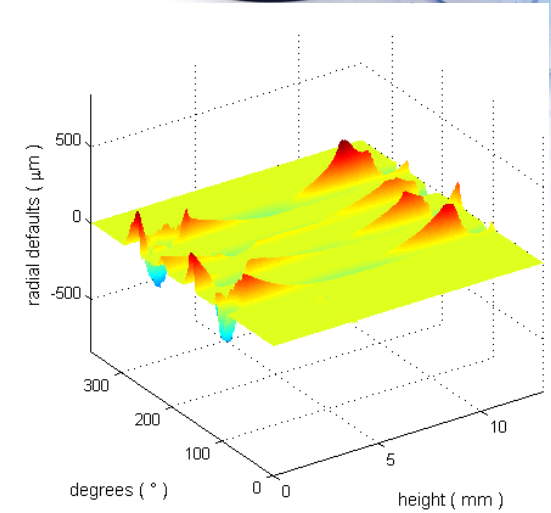
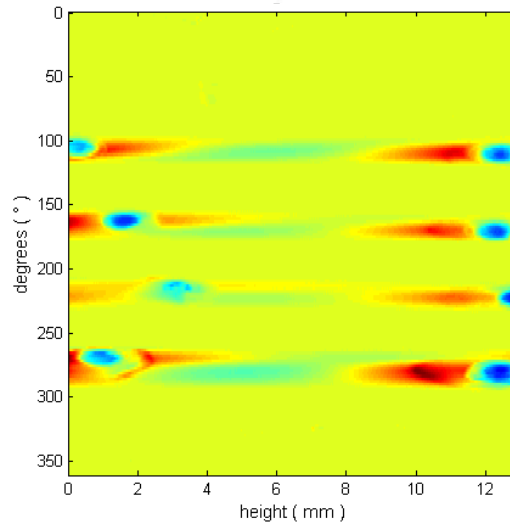
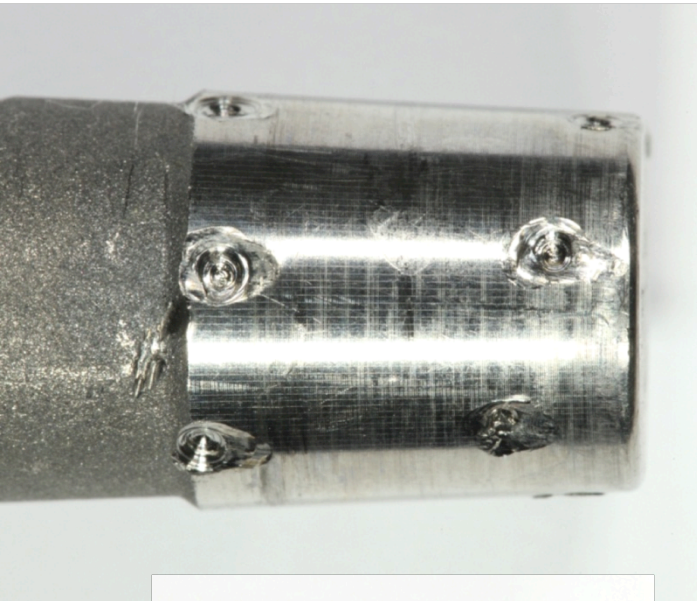


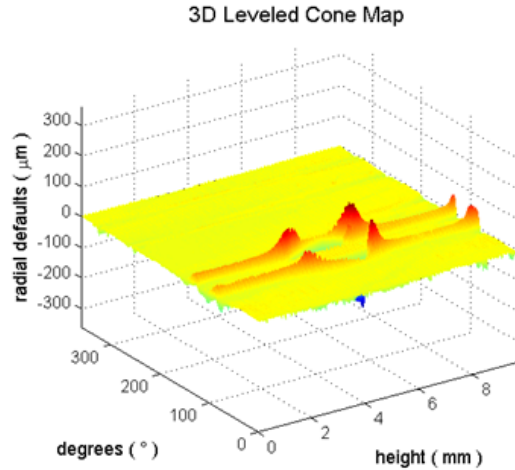
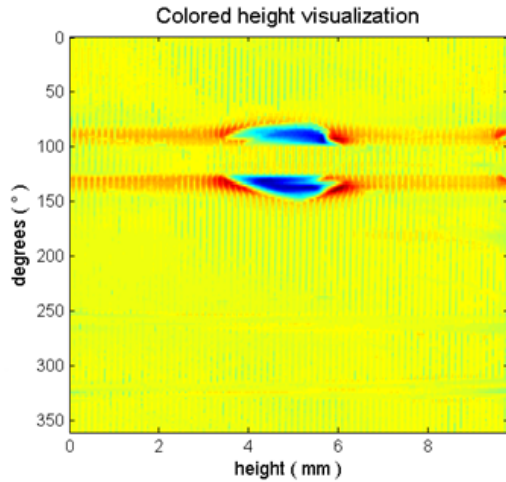
Goldberg: 2
Material lost: 1.06mm³

Material loss = 17.031 mm³

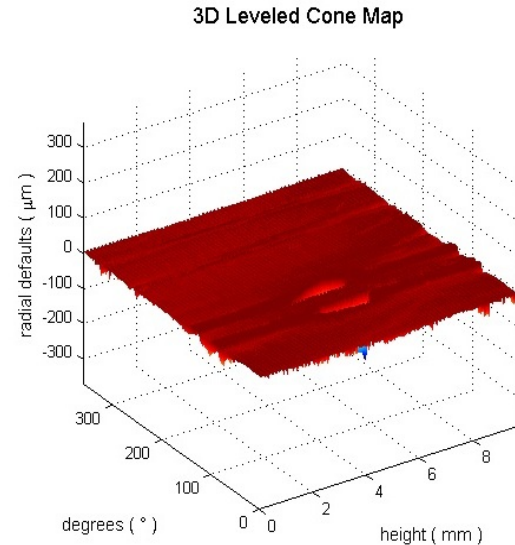
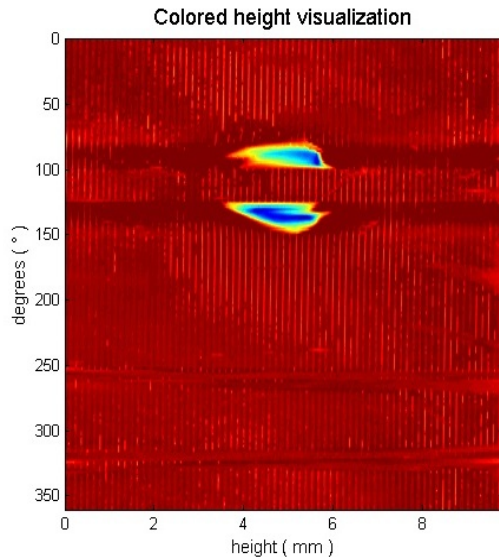


- Clear delineation of wear area in head taper
- Stem trunnion 100% of area in contact.
- Retrieval tends to damage trunnion surface.
- No clear datum from which to measure material loss

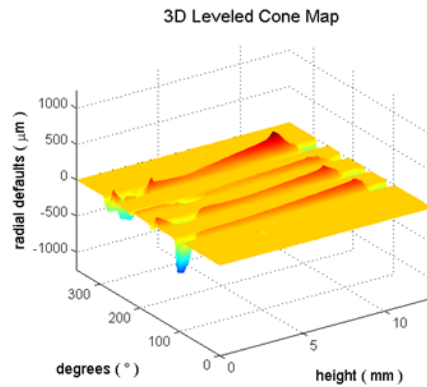
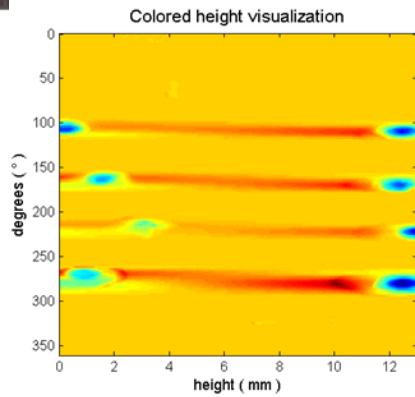




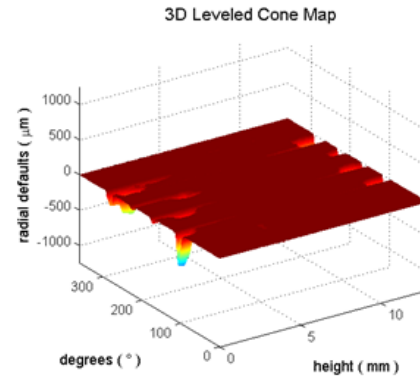
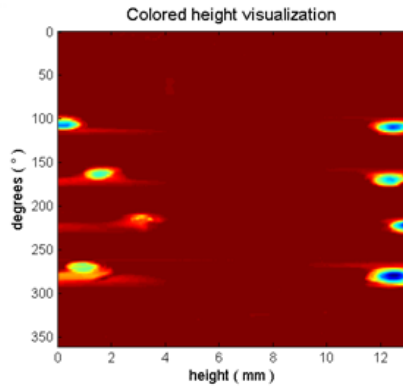
Analysis with debris
Material volume associated
with defects 43.553 mm^3



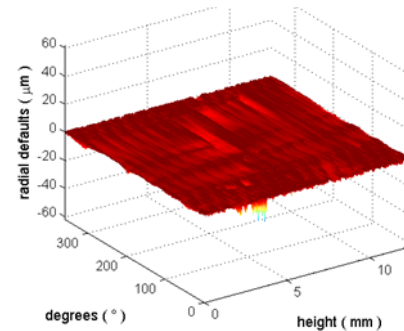
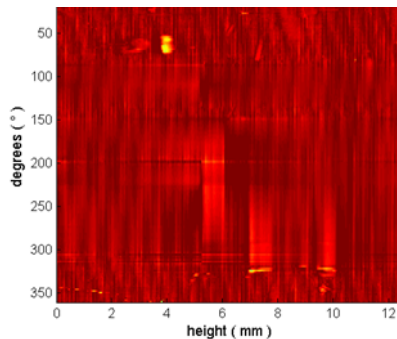
Analysis after debris removal
Material volume associated
with defects loss 3.183 mm^3



Analysis with defect and debris
Material loss 151.442 mm³



Analysis with defect
Material loss 6.084 mm³



Analysis
Material loss 0.441 mm³

- Method assessed by Taylor Hobson and found to be accurate to within 1% (volume) using NPL derived algorithm and reference datasets.
- Further method trialling using retrieval components for case studies.
- Hardware integration and uncertainty mapping are in development.

- Essential to measure tapers to understand failure and *in-vivo* behaviour.
- Quantification of stem material loss shows that minimal material lost from stem.
- Extraction damage can be discounted from analysis.
- Taper form deviation must be accounted for.
- Determination of unworn geometry key THE factor in accuracy of measurement method
- Material loss on stem not quantitatively possible (no datum), local variations only

- Prof Paul Scott
- Dr Shaojun Xiao

- Mr Alister Hart
- Mr John Skinner



