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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

## Mail Online

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

## DR

Metal hip patients to  
be monitored

## sky NEWS HD

Fears Over Hip  
Replacement 'Poisoning'

## Herald Sun

Stories start here.

Australians hit by hip  
replacement recall

## [nzherald.co.nz](http://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

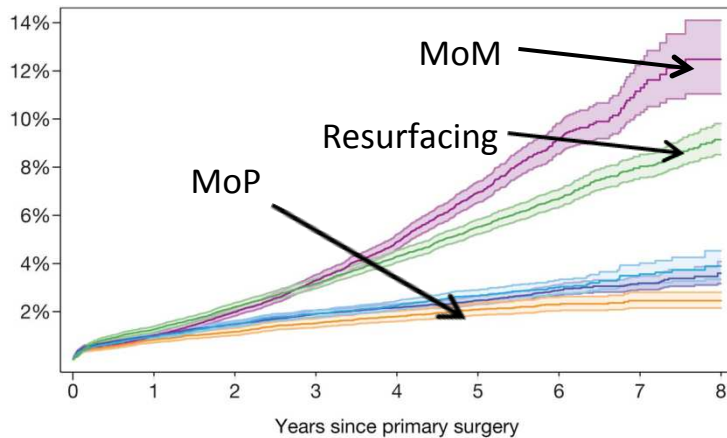
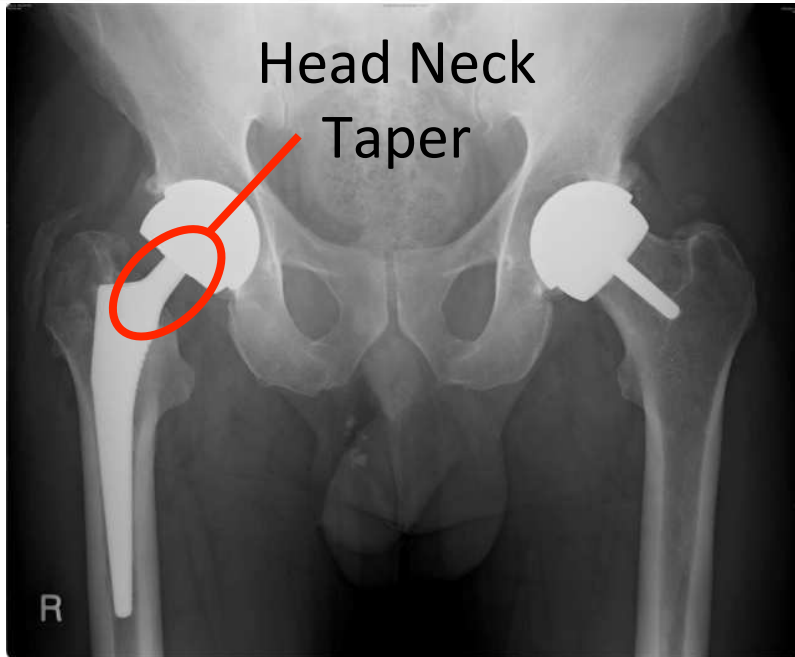
- **>750,000 MoM in US.**
- Bearing surface measurement important.
- Currently no consensus on procedure, strategy etc.
- Need for further development of standards and standardised practices.



Standards Worldwide - Home

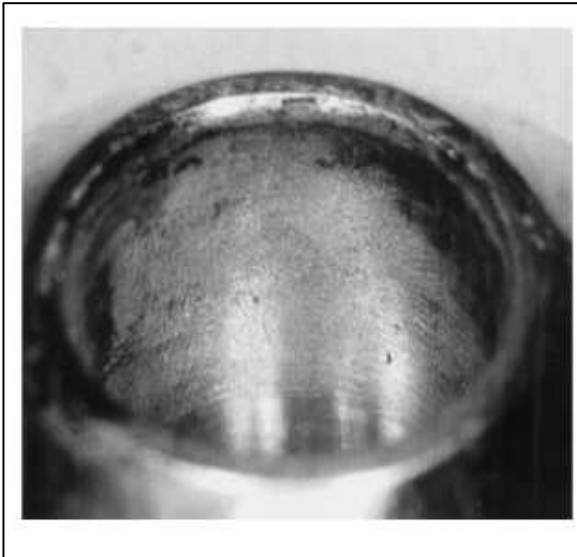






NJR, 9<sup>th</sup> Annual Report, 2012

- 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



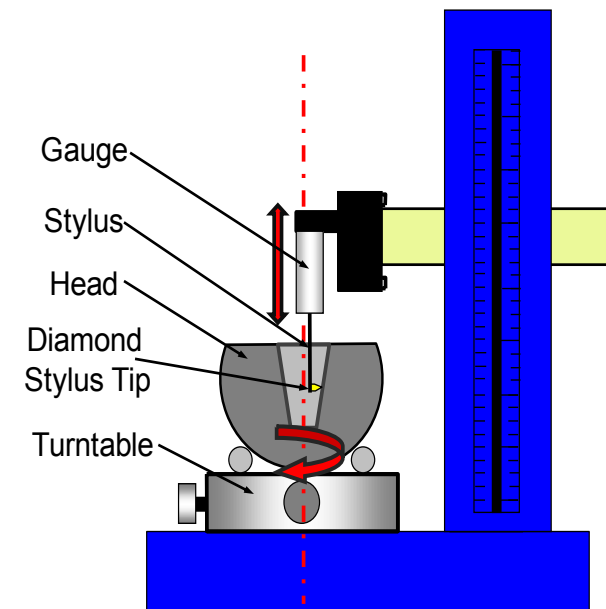
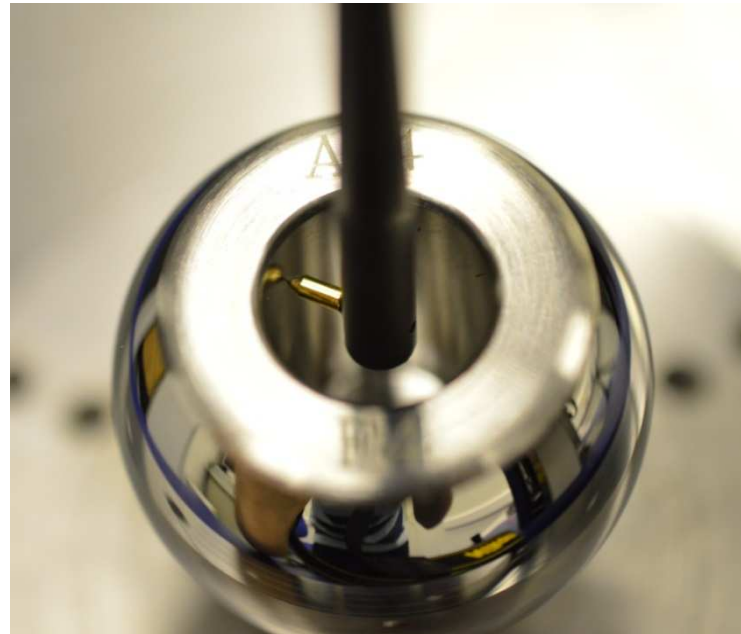
Langton et al, 2012



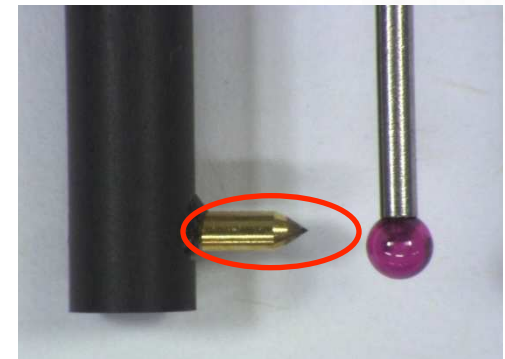
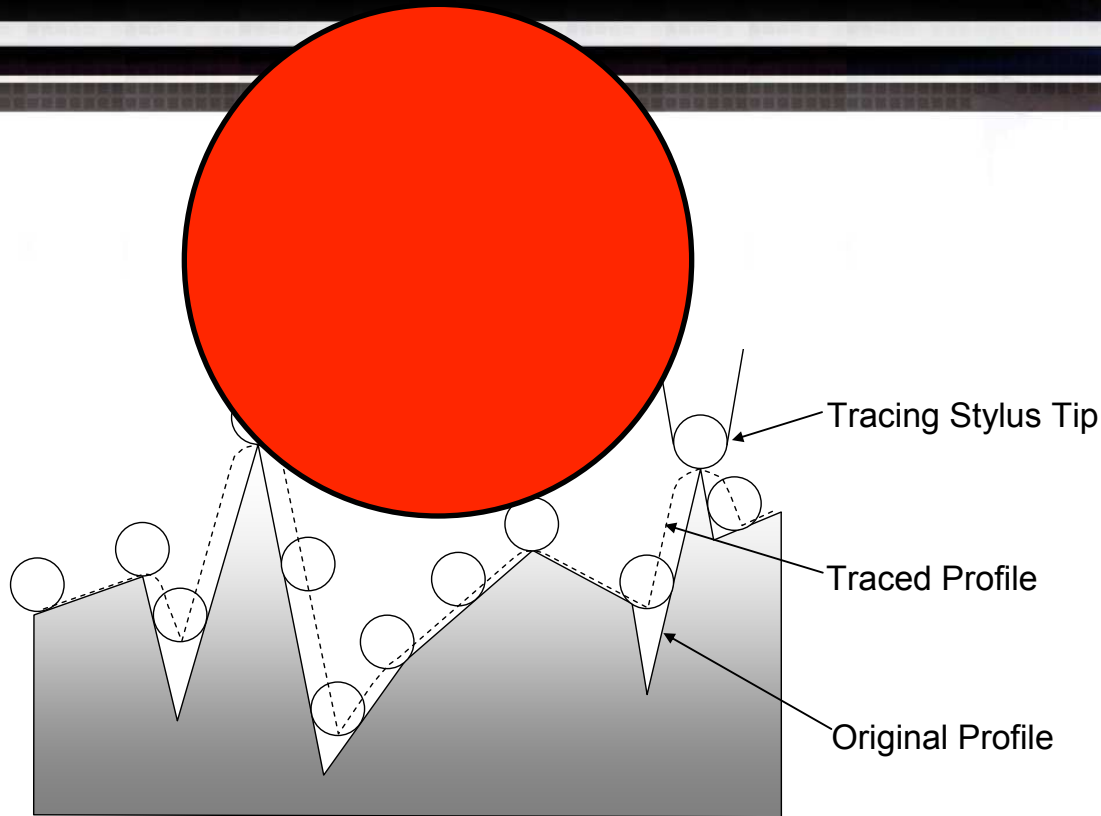
Matthies et al, 2012

- 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  $\mu\text{m}$  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.

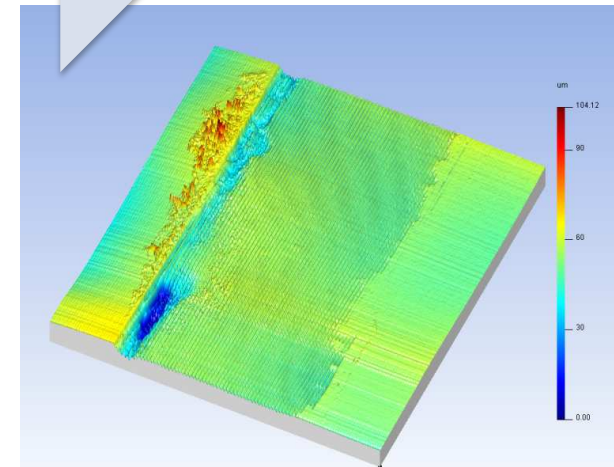
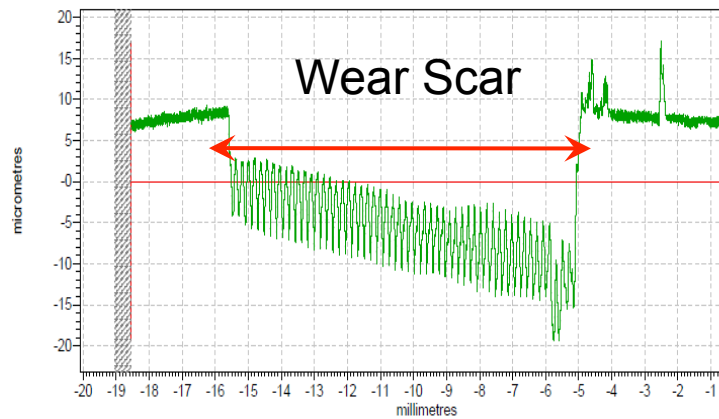
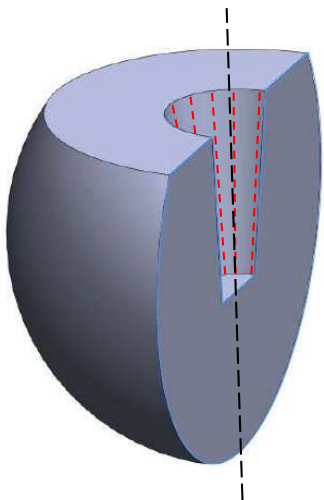
Vertical trace  
measurement

Two stage  
form removal

Identification  
of worn  
regions

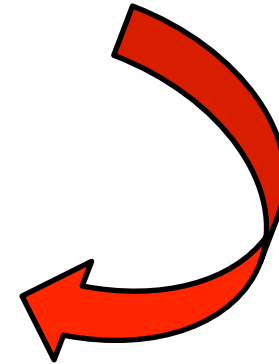
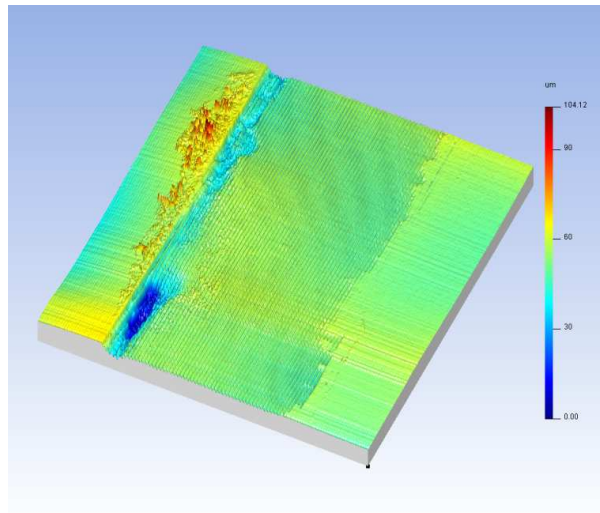
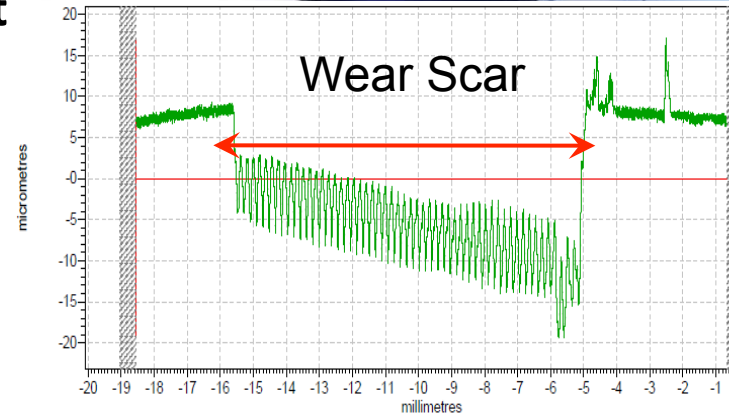
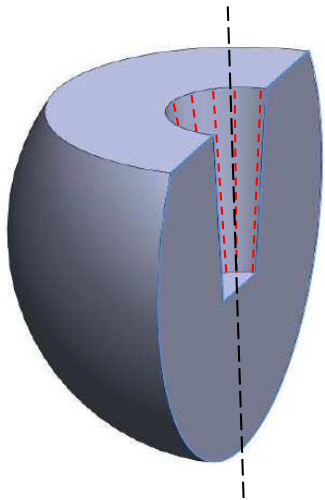
Removal of  
debris

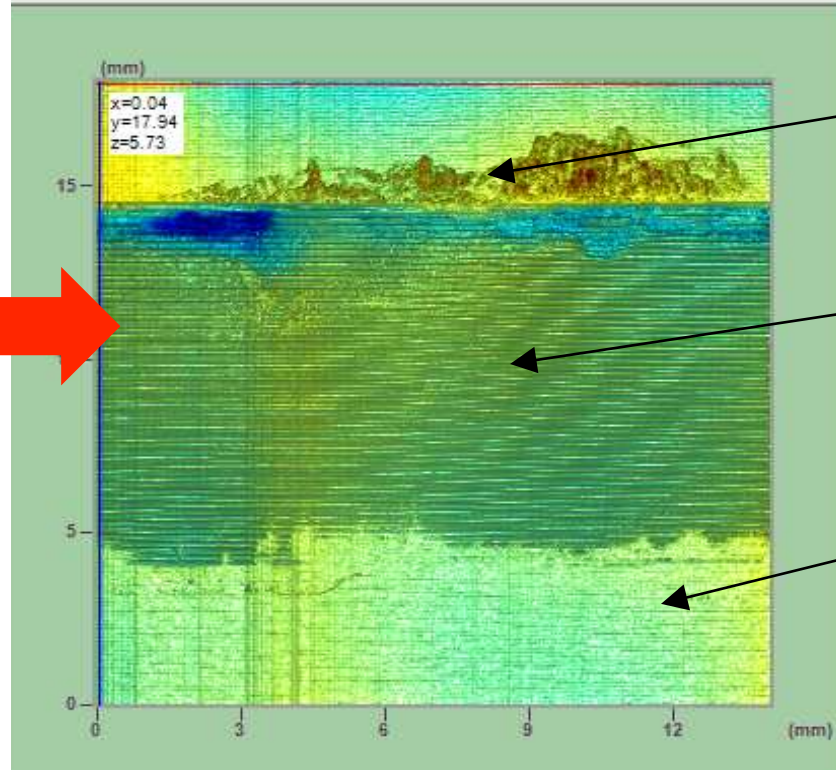
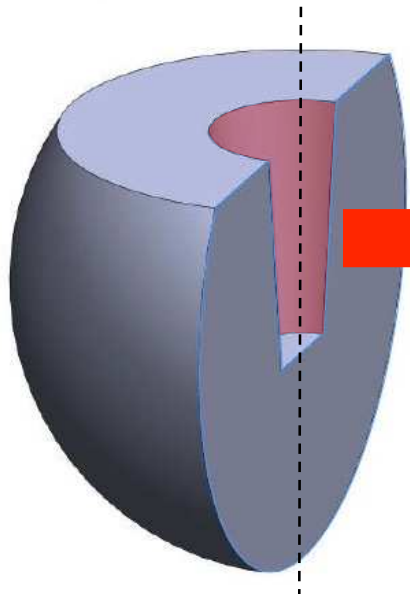
Material loss  
calculation



## 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

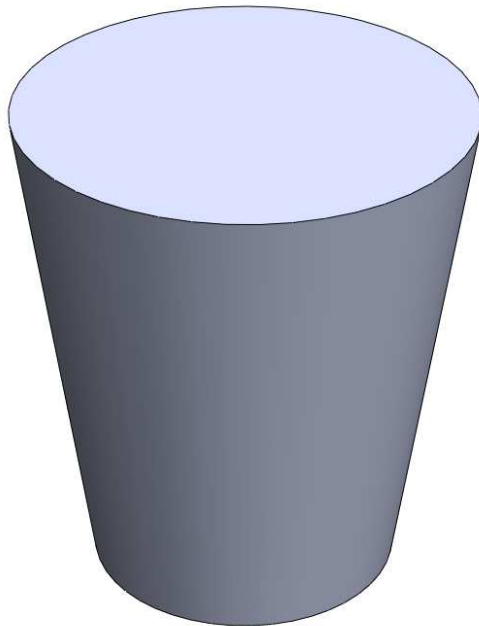
360 vertical profiles, angular spacing of  $1^\circ$ ,

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

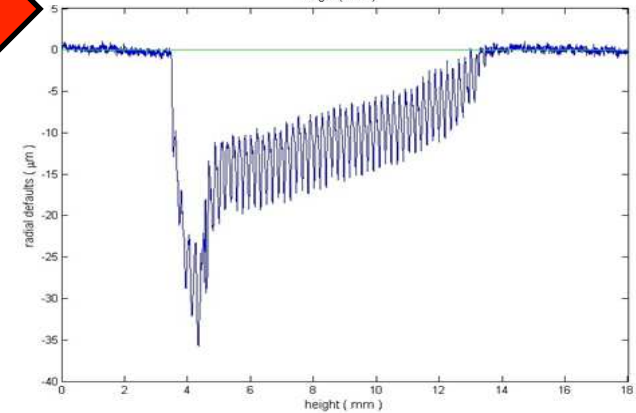
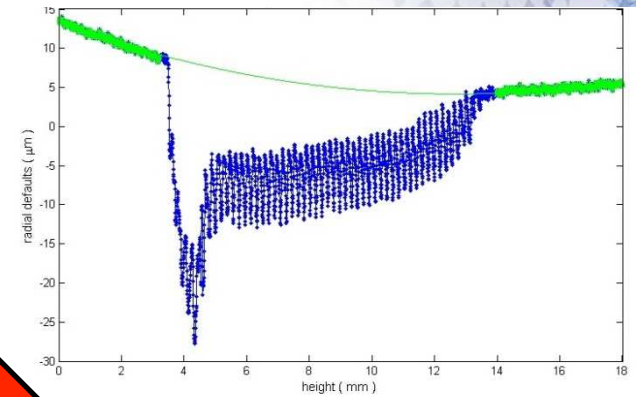
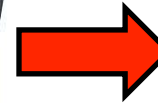
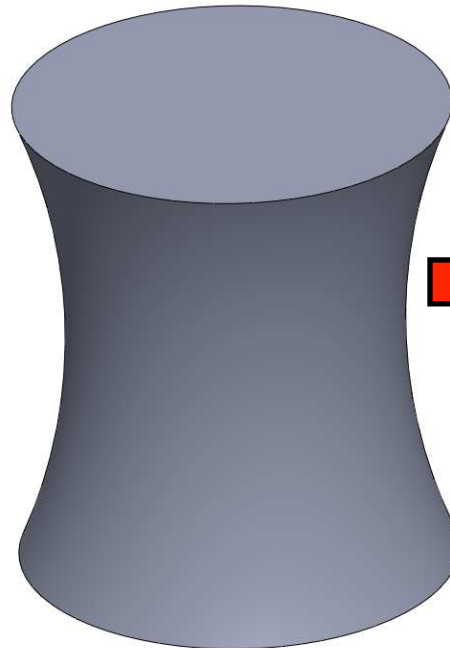
**Total number of data points 2.5 million**



Primary: conic

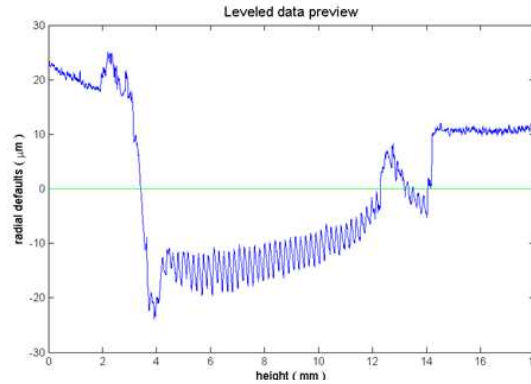
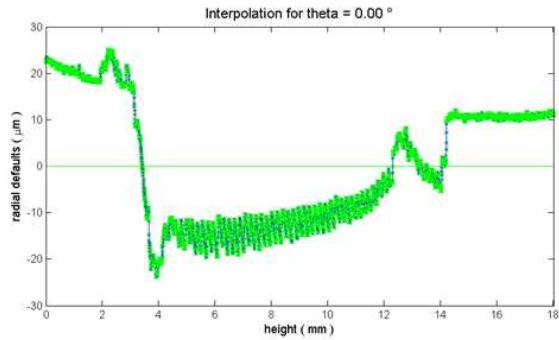


Secondary: quadratic

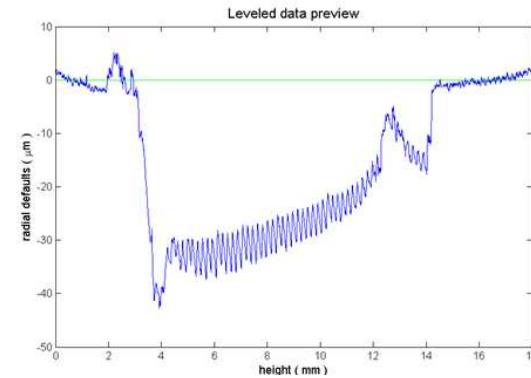
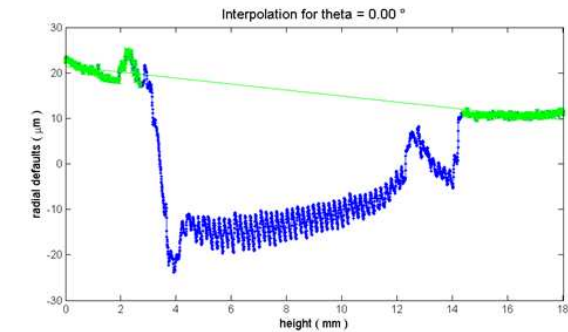


Two stage form removal process ~ 35% of female tapers had secondary form component (quadratic)

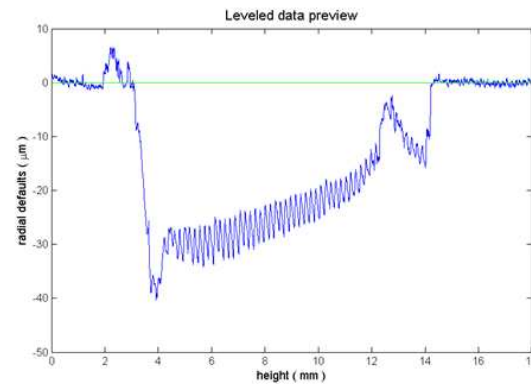
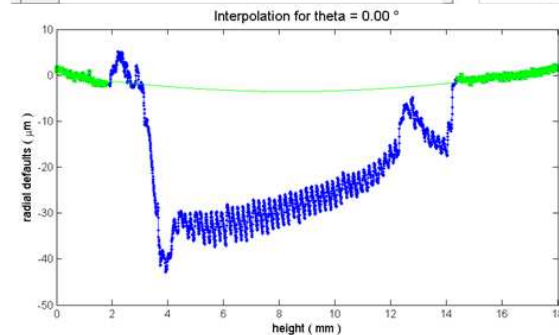
Can give fitting error of up to 5μm



Average fitting  
Material loss: 13.69 mm<sup>3</sup>



Linear fitting  
Material loss 12.36 mm<sup>3</sup>



Parabolic fitting  
Material loss 10.76 mm<sup>3</sup>

➤ Conical form → Cylindrical coordinates

General expression of a volume :

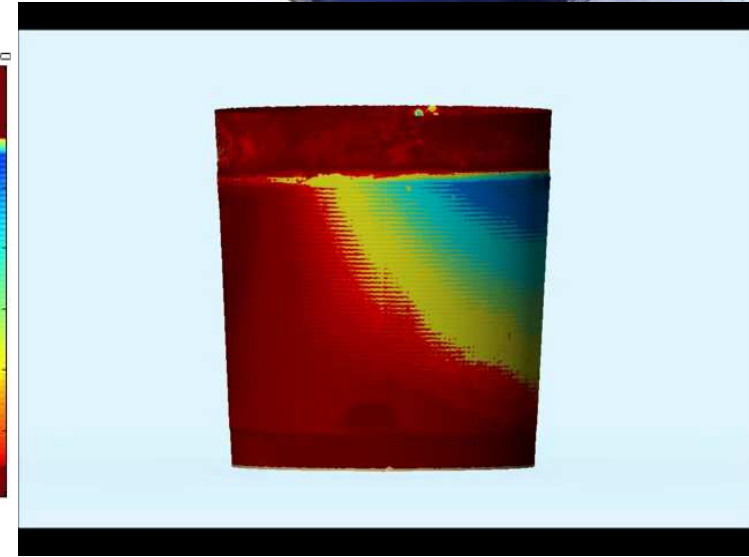
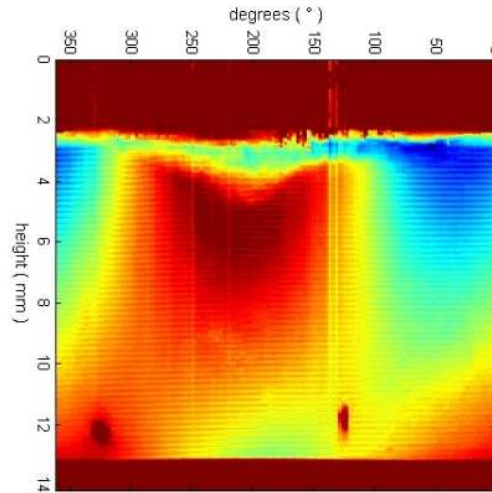
$$V = \int_{\theta=0}^{2\pi} \int_{z=0}^h \int_{r=0}^{r(z,\theta)} dr (rd\theta) dz = \int_{\theta=0}^{2\pi} \int_{z=0}^h \frac{r^2(z,\theta)}{2} dz d\theta$$

➤ Application :

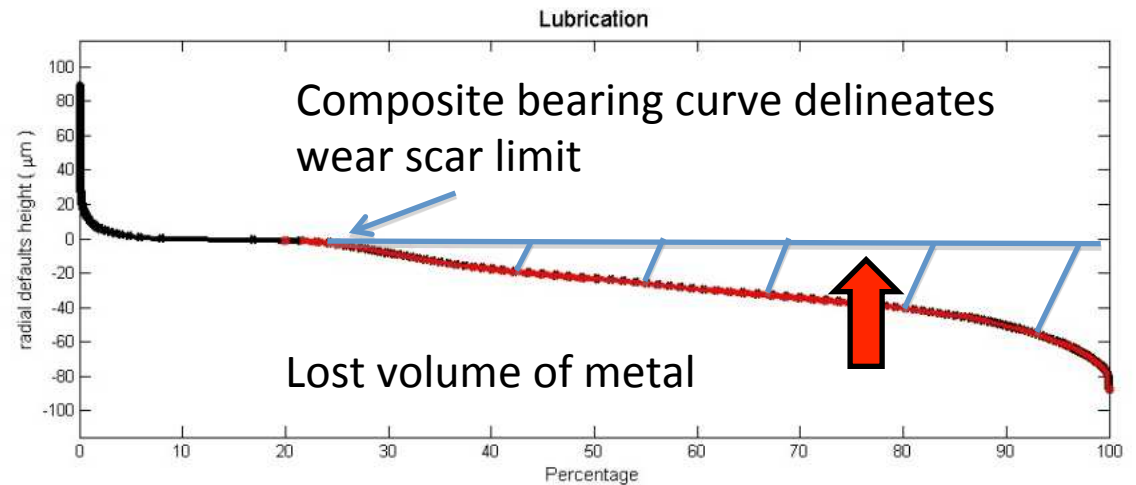
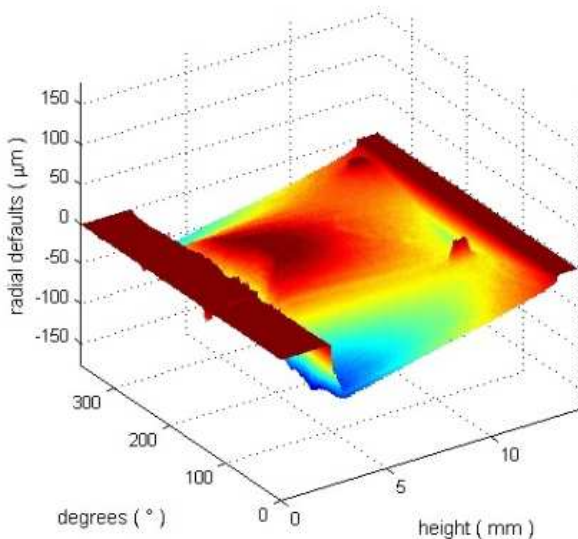
$$\begin{cases} V_{max} = \frac{1}{2} \int_{\theta=0}^{2\pi} \int_{z=0}^h (R_{moy}(z,\theta) + h_{max})^2 dz d\theta \\ V = \frac{1}{2} \int_{\theta=0}^{2\pi} \int_{z=0}^h (R_{moy}(z,\theta) + \varepsilon_{cut}(z,\theta))^2 dz d\theta \end{cases}$$

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

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



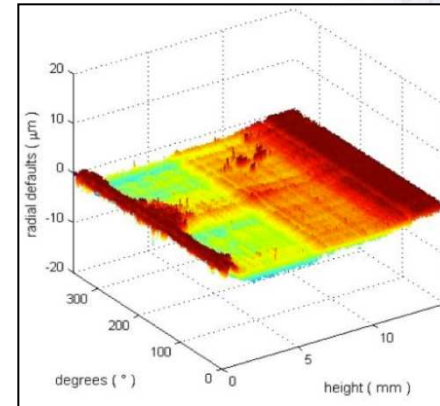
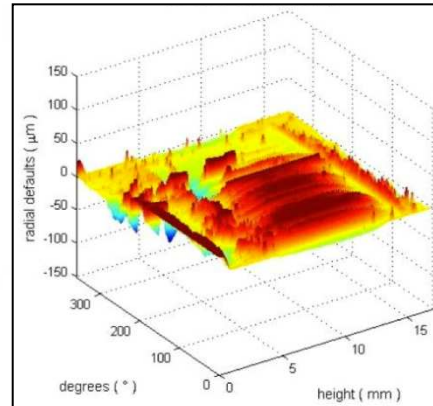
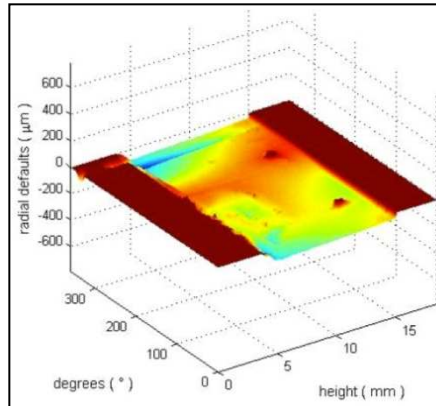
3D Levelled Cone Map





# Head Taper Results

## Goldberg vs Quantitative Metrology



**Goldberg: 4**  
**Material lost: 25.19mm<sup>3</sup>**



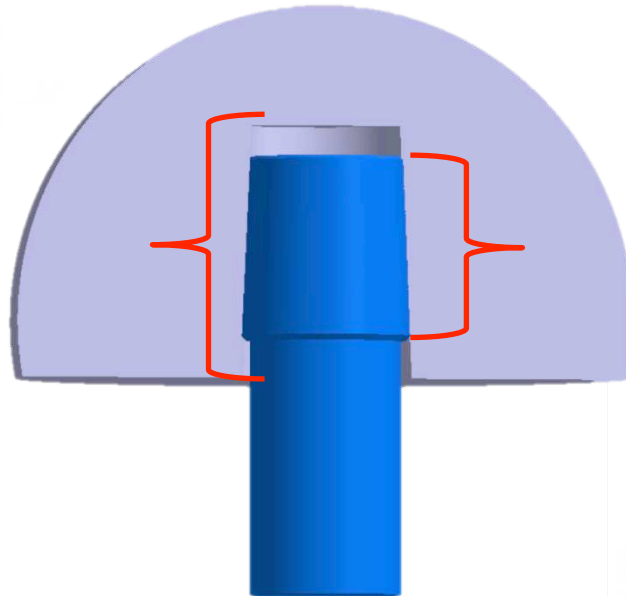
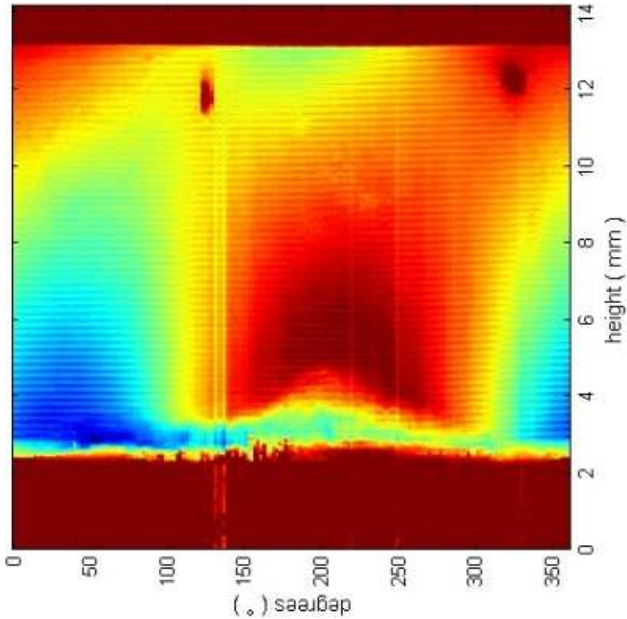
**Goldberg : 3**  
**Material lost: 6.21mm<sup>3</sup>**



**Goldberg: 2**  
**Material lost: 1.06mm<sup>3</sup>**

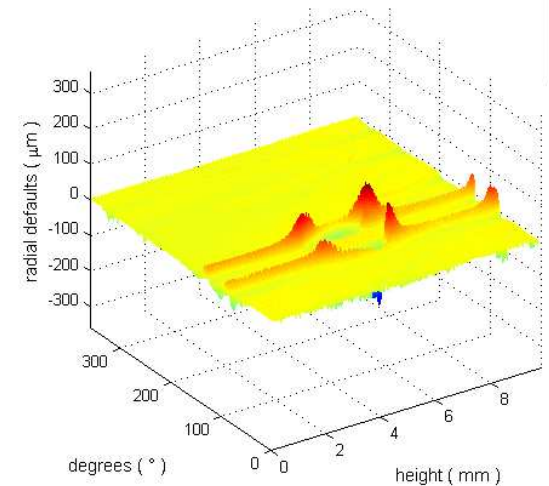
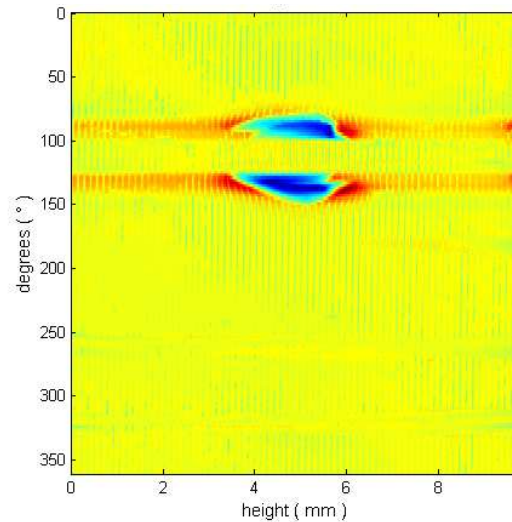
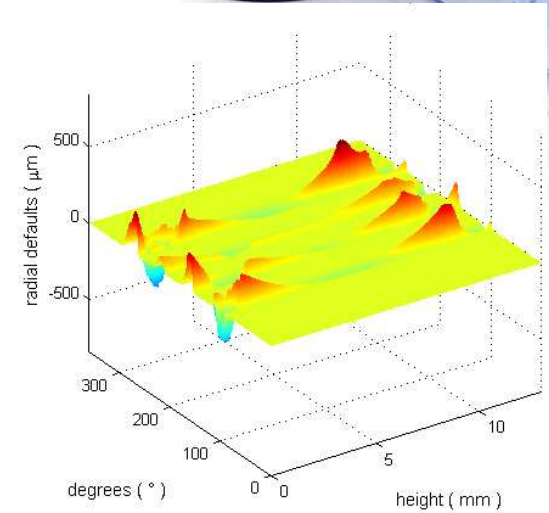
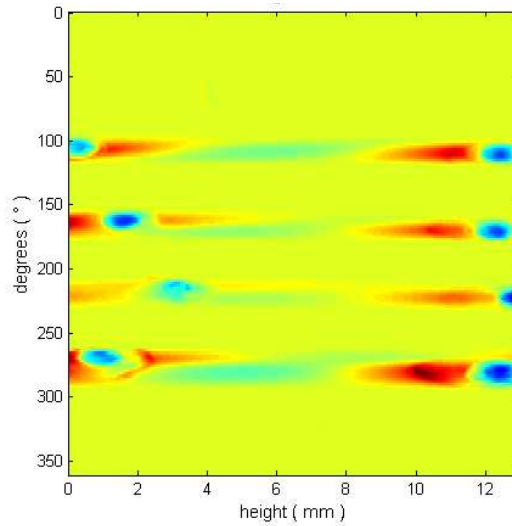
# Taper interface

Material loss = 17.031 mm<sup>3</sup>

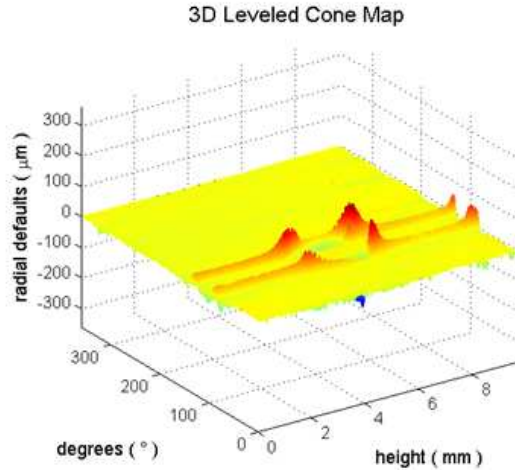
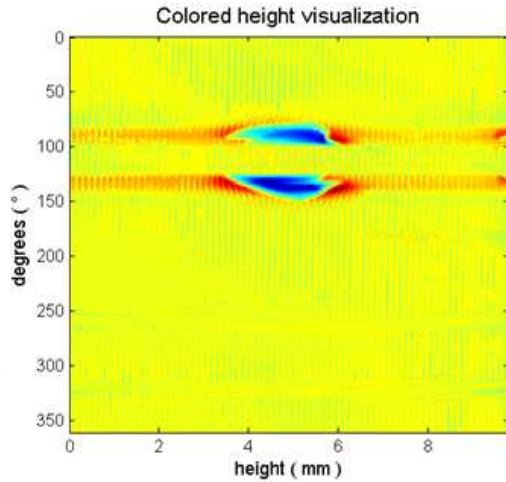


- Clear delineation of wear area in head taper
- Stem trunnion 100% of area in contact.
- Retrieval tends to damage trunnion surface.
- No clear datum from which to measure material loss

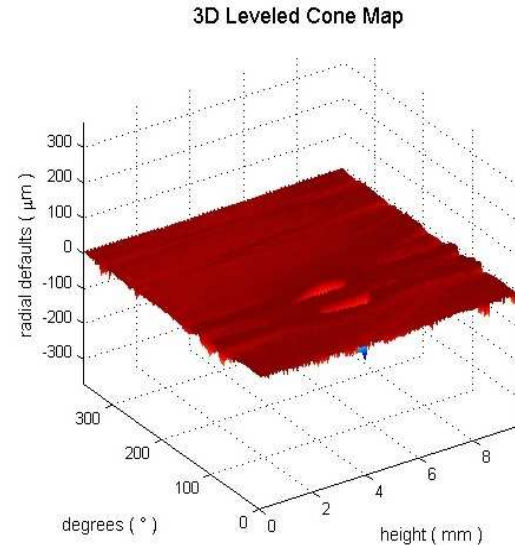
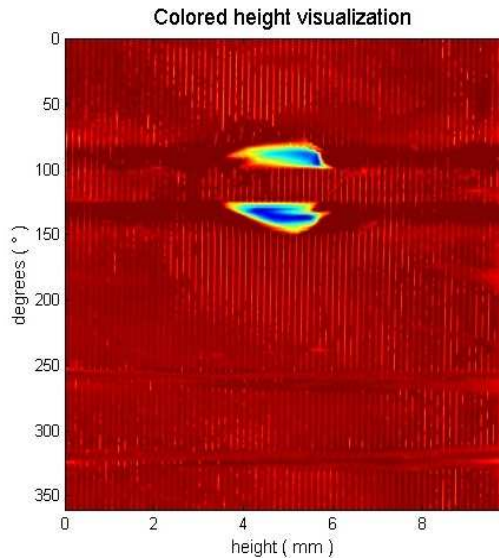




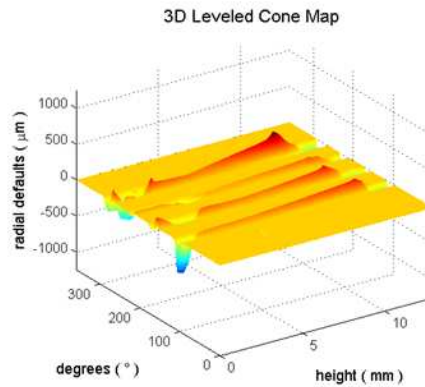
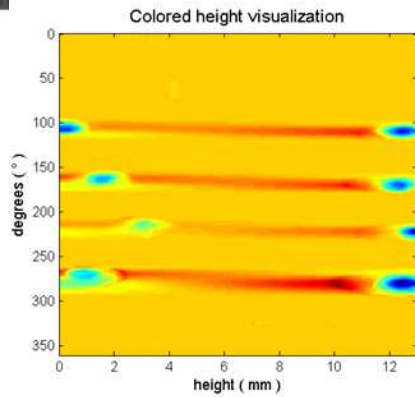




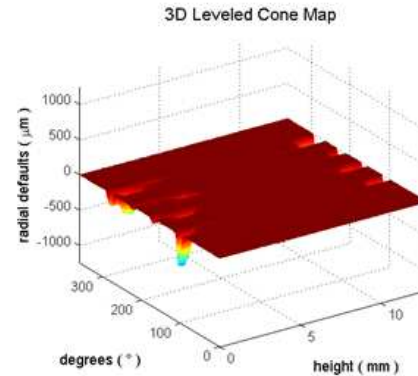
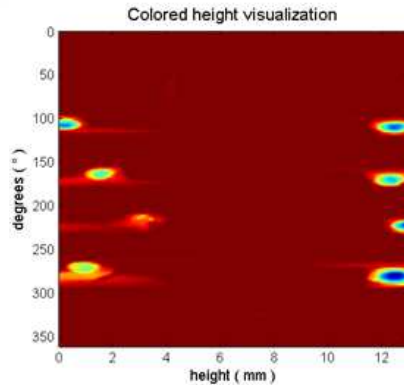
Analysis with debris  
Material volume associated  
with defects  $43.553 \text{ mm}^3$



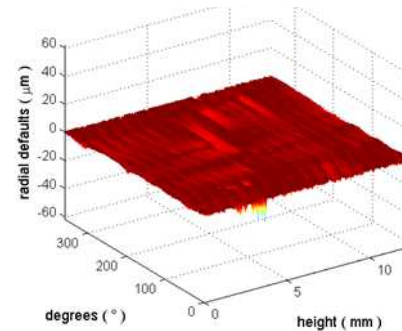
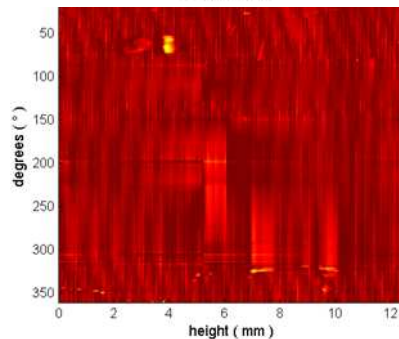
Analysis after debris removal  
Material volume associated  
with defects loss  $3.183 \text{ mm}^3$



Analysis with defect and debris  
Material loss 151.442 mm<sup>3</sup>



Analysis with defect  
Material loss 6.084 mm<sup>3</sup>



Analysis  
Material loss 0.441 mm<sup>3</sup>

- 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



# Thank you

