Plasticity Induced Damage on Grinding of polycrystalline γ-TiAl

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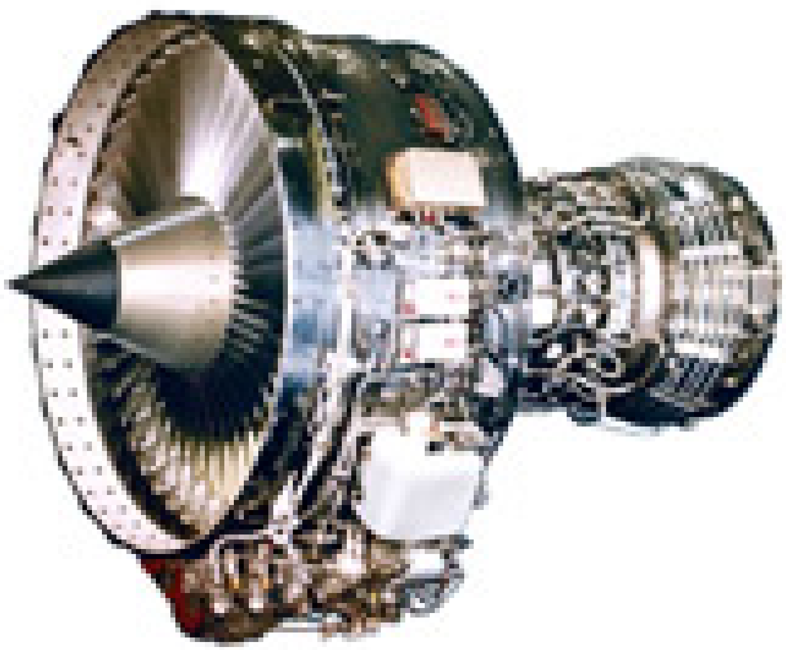
Technological Problem

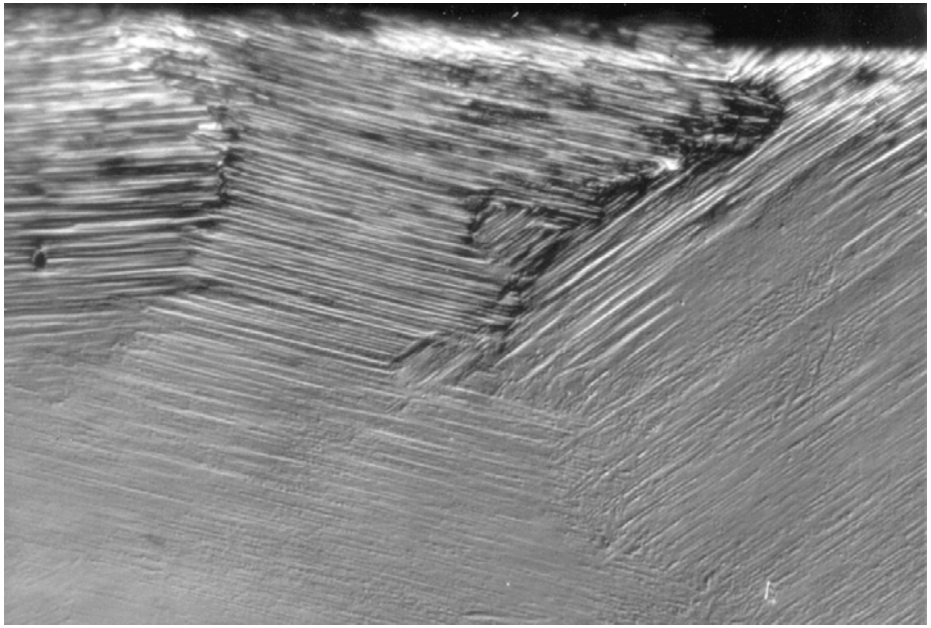


- Use of Intermetallic compounds
  - Light weight
  - Good mech. props. @ H.Temp.
  - **Brittle at low temperature**
- Damage on manufacturing
- Catastrophic failure on service

Damage assessment during manufacturing is fundamental

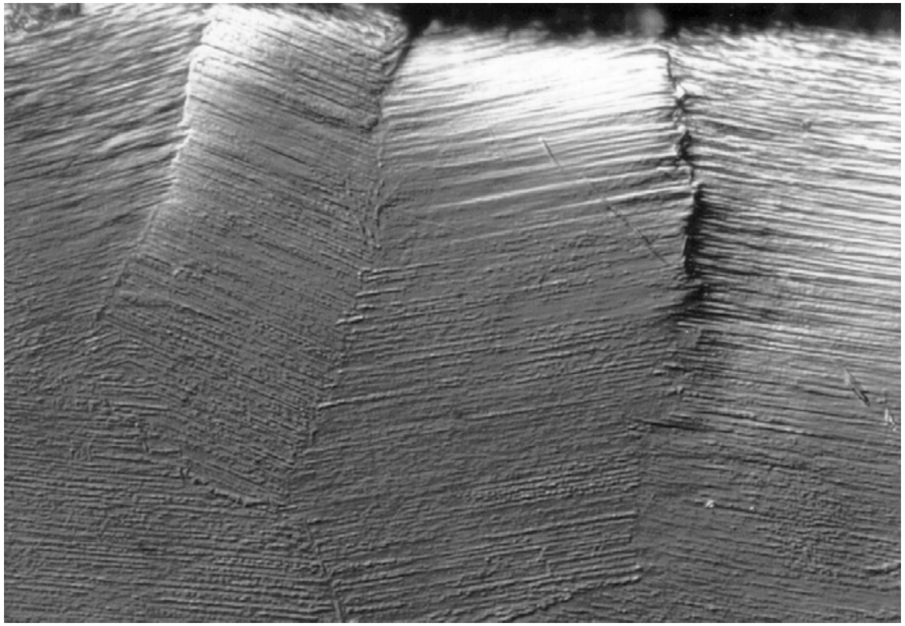
Deformation and Cracking

(Nelson 1997)



50 mm

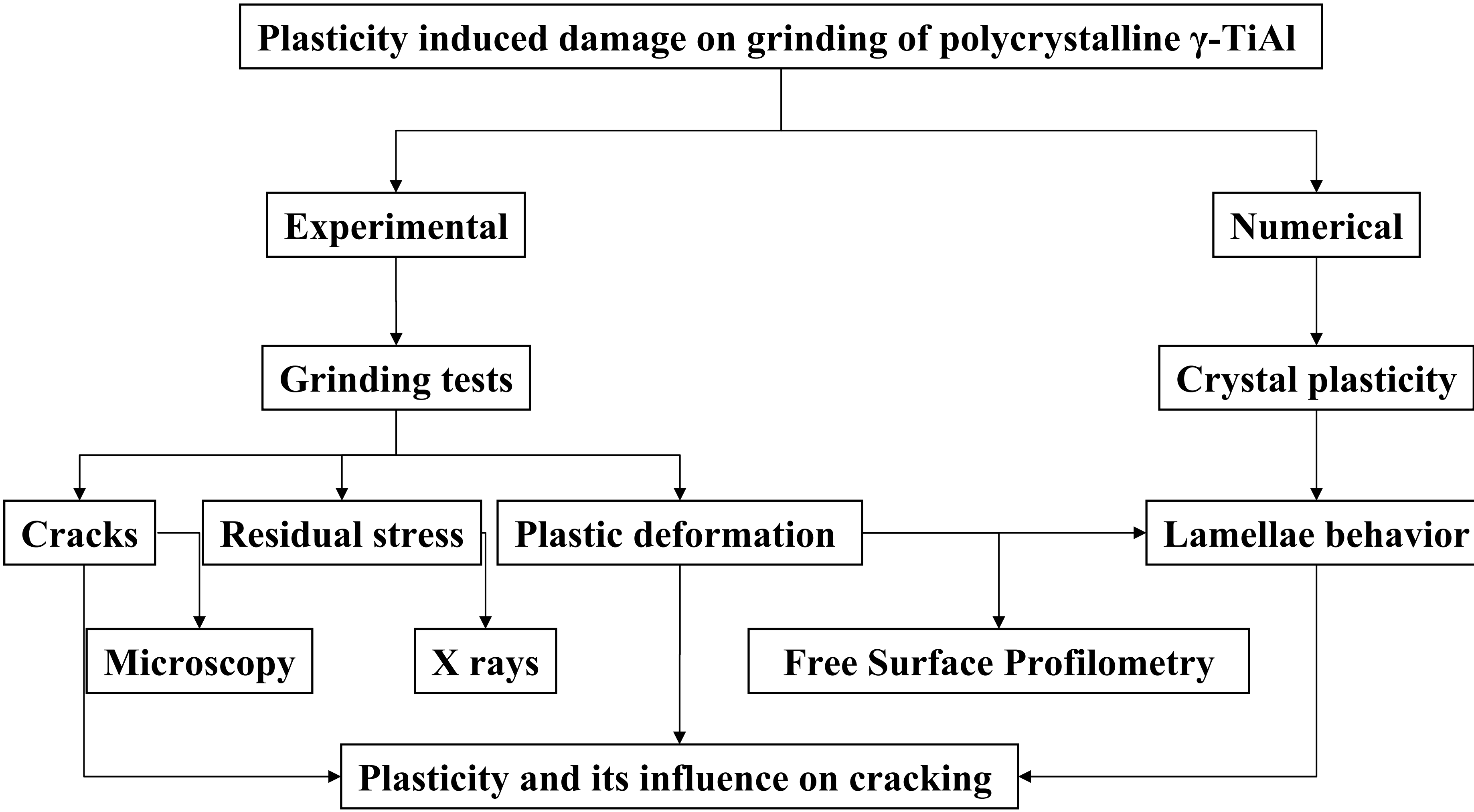
•Preferential deformation directions



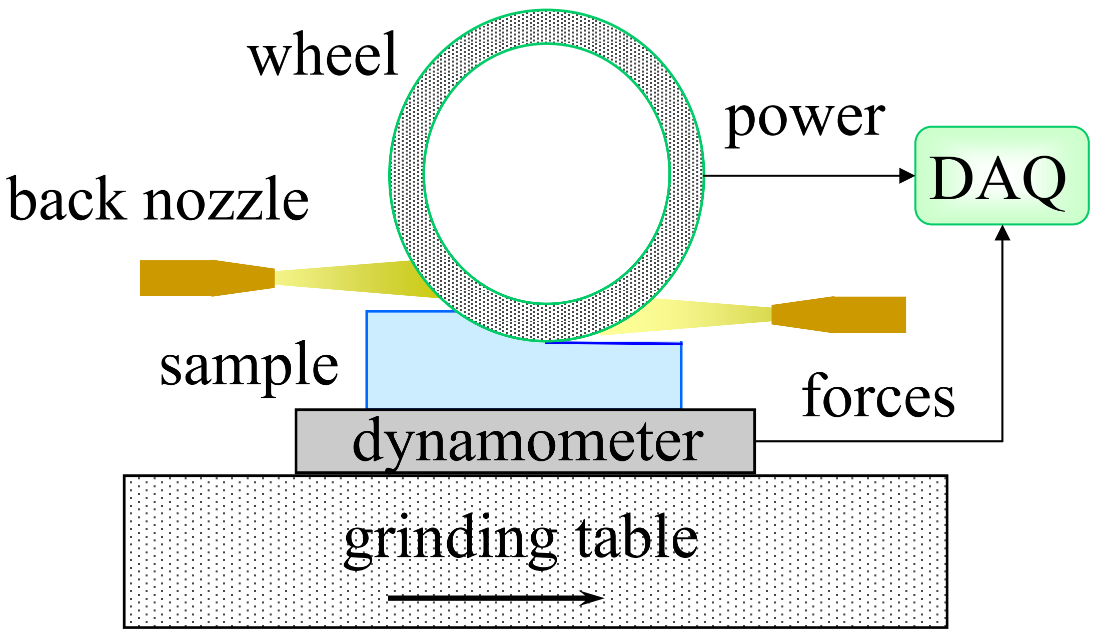
50 mm

•Cracking at grain boundaries

Overview


Plasticity induced damage on grinding of polycrystalline γ-TiAl
Experimental
Numerical
Grinding tests
Crystal plasticity
Cracks
Residual stress
Plastic deformation
Lamellae behavior
Microscopy
X rays
Free Surface Profilometry
Plasticity and its influence on cracking

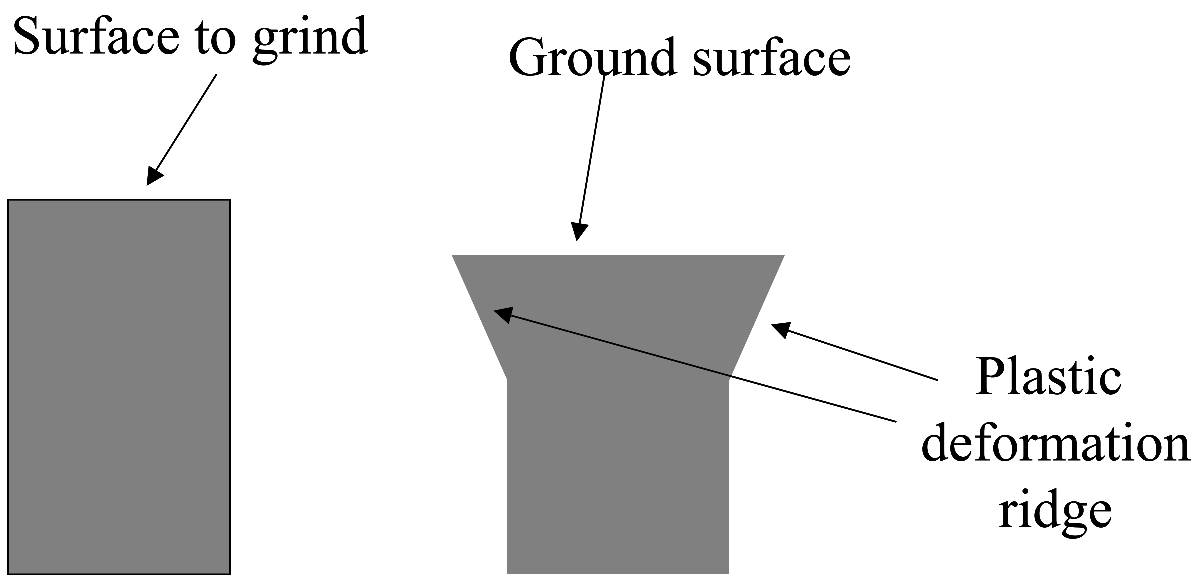
Grinding



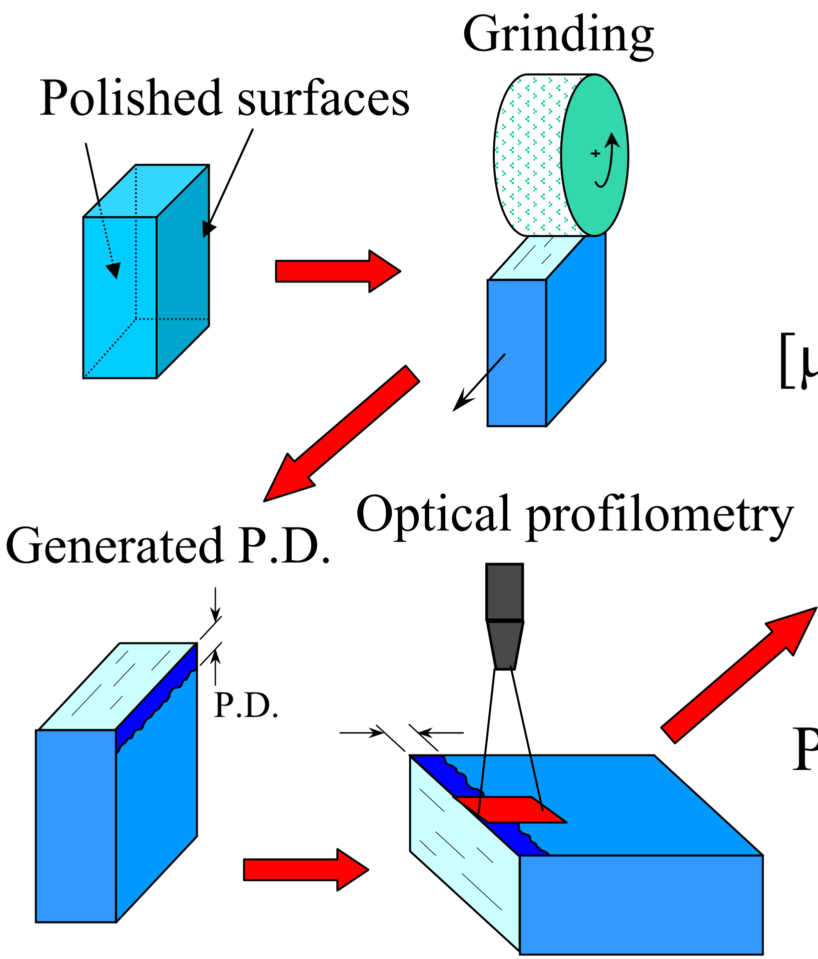
- Workpiece material
- Feed rate
- Depth of cut
- Wheel type
- Wheel speed
- Wheel direction
- Cooling conditions
- Machine stiffness

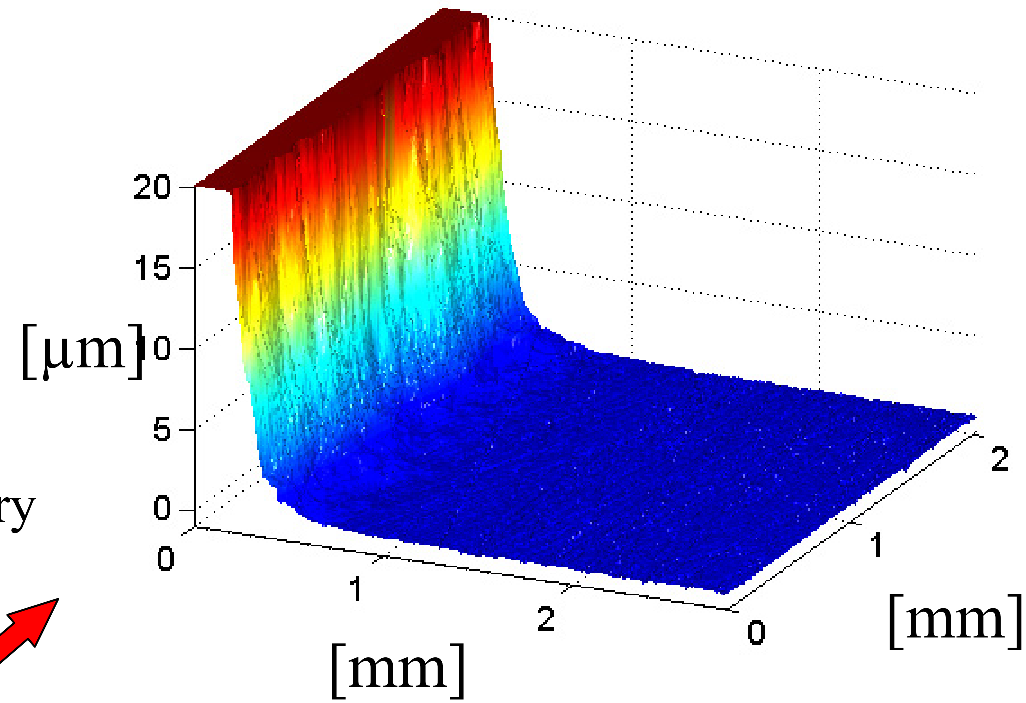
Evaluation of grinding variables on subsurface damage

Lateral Material Displacement



Subsurface Plastic Deformation





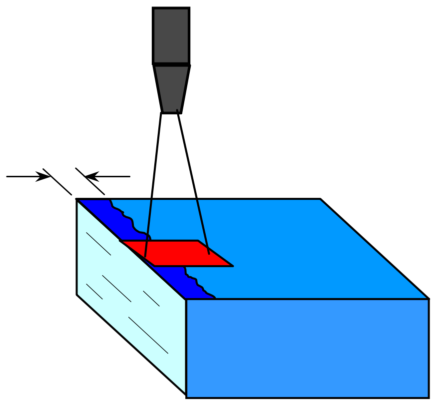
Processing

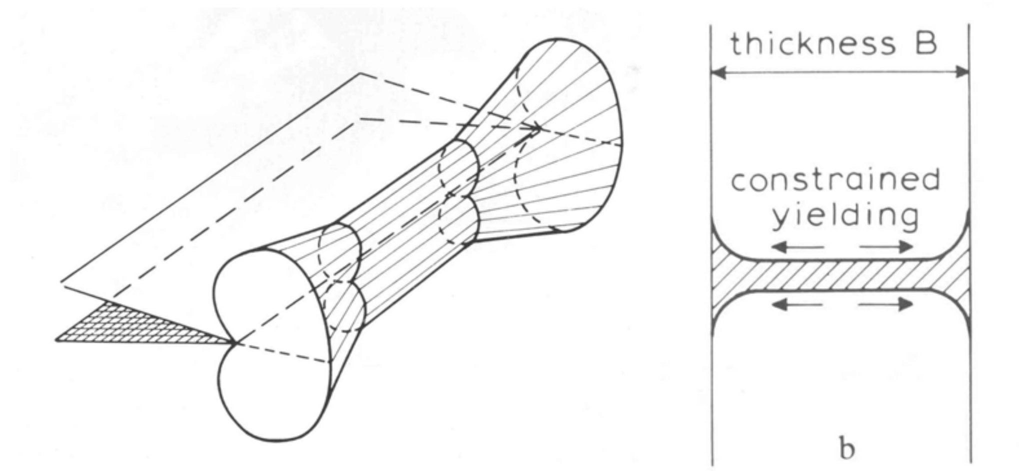
Scanned Area: 2.8 x 2.1 mm

X-Y axis resolution: 4.4 μm

Vertical resolution: O(nm)

Relevance of the Measurement

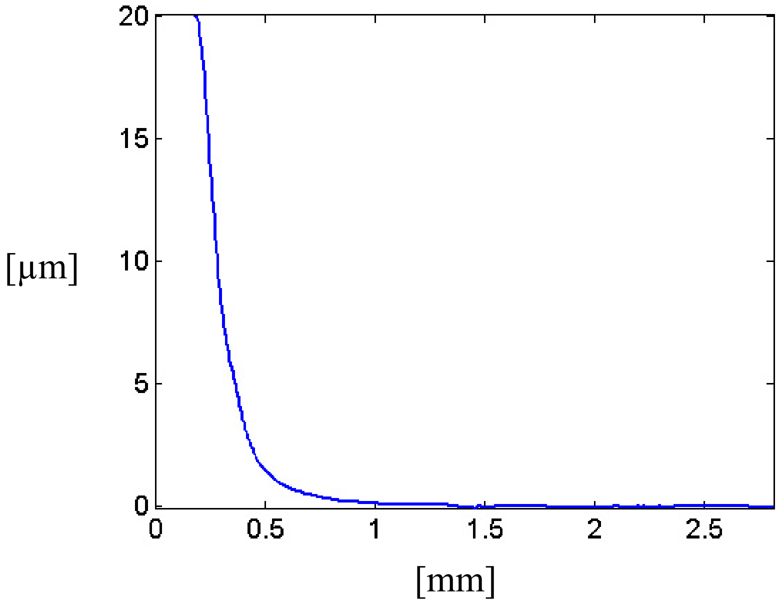


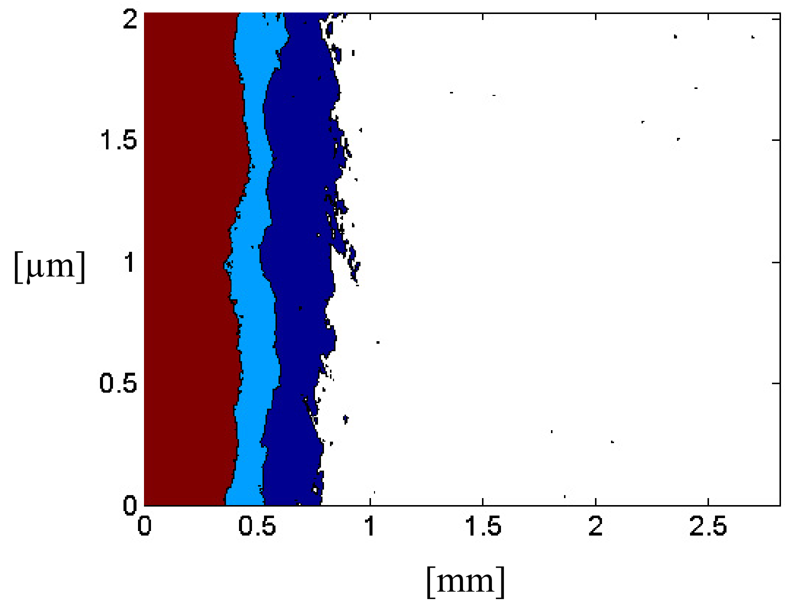


Plastic constraint factor = 3

Upper boundary for PDD

P D: Image Analysis Techniques





•**Plane fitting**: average measurement
•Average out-of-planarity measurement
•1 data point/scanned image

•Fitting of best plane on undeformed area
•Measure of surface average vertical deviation from fitted plane as a function of distance from ground surface
•Choosing of a threshold value to define PD
•Robust to missing points and surface finishing

•**Contour plot**: point to point measurement
•Point to point measurement
•# data points ≥ image width / X-Y resolution (not a function)

•Allows computation of PD dispersion at grain scale
•Choosing of a threshold value to define PD
  •(3 - 1- 0.25 μm in the figure)
•Very sensitive to surface finishing

Grinding Experimental Matrix

Grit size	Grit shape	Wear	Depth of cut	Table speed	Replic.	Total
2	2	2	2	2	2	64

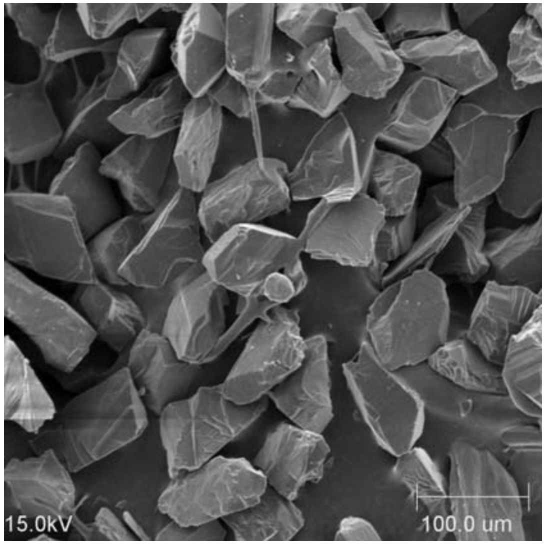
- Full factorial: 32 different runs
  - Variables values
  - *Grit size:* Mesh 60-80 (232 μm) Mesh 270-325 (54 μm)
  - *Grit shape:* Blocky Angular
  - *Wear:* 0.05 mm^3/mm^2 2.5 mm^3/mm^2
  - *Depth of Cut:* 20 μm 50 μm
  - *Table speed:* 20 mm/sec 80 mm/sec

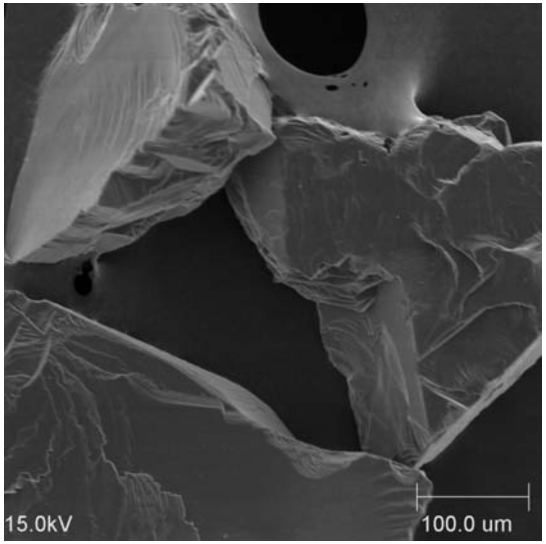
- PDD Measurements
  - 3 each side

- Total PDD measurements: 384

Grinding Wheel Diamond Abrasives

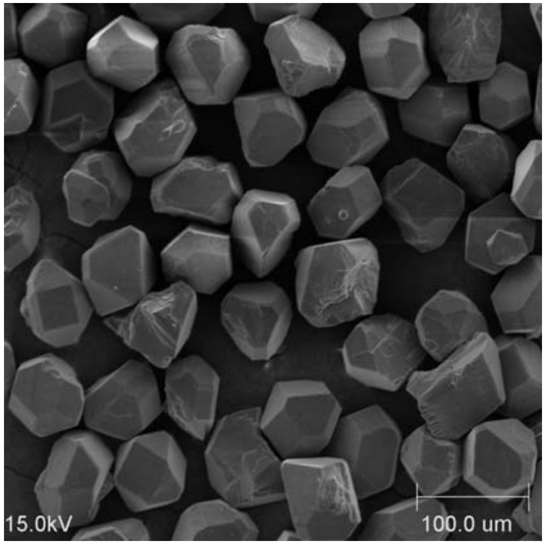
Wheel 63: SA
MBG 300
Grit: 270-325
(54 μm avg.)

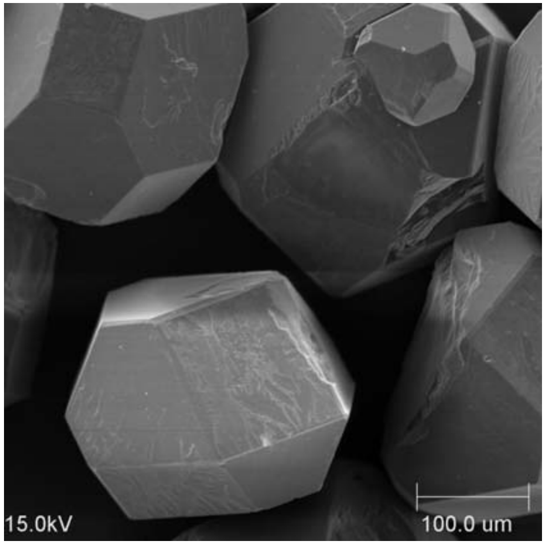




Wheel 65: LA
MBG 300
Grit: 60-80
(232 μm avg.)

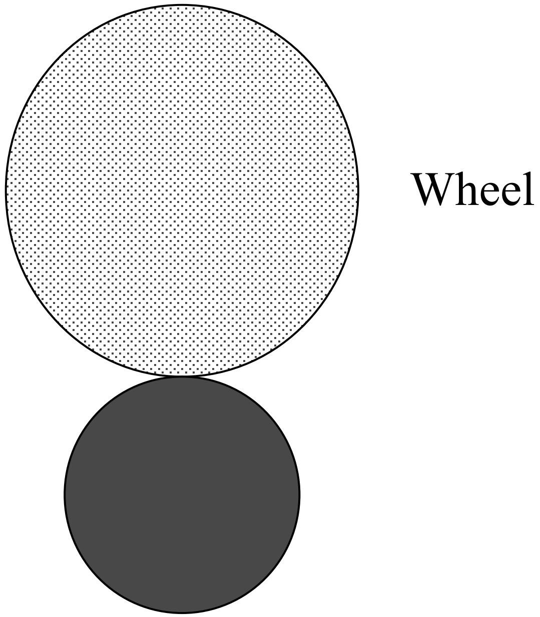
Wheel 64: SB
MBG 660
Grit: 270-325
(54 μm avg.)



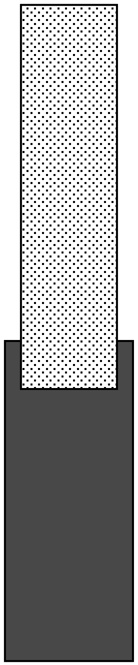


Wheel 61: LB
MBG 660
Grit: 60-80
(232 μm avg.)

Superabrasive Wheel Conditioning



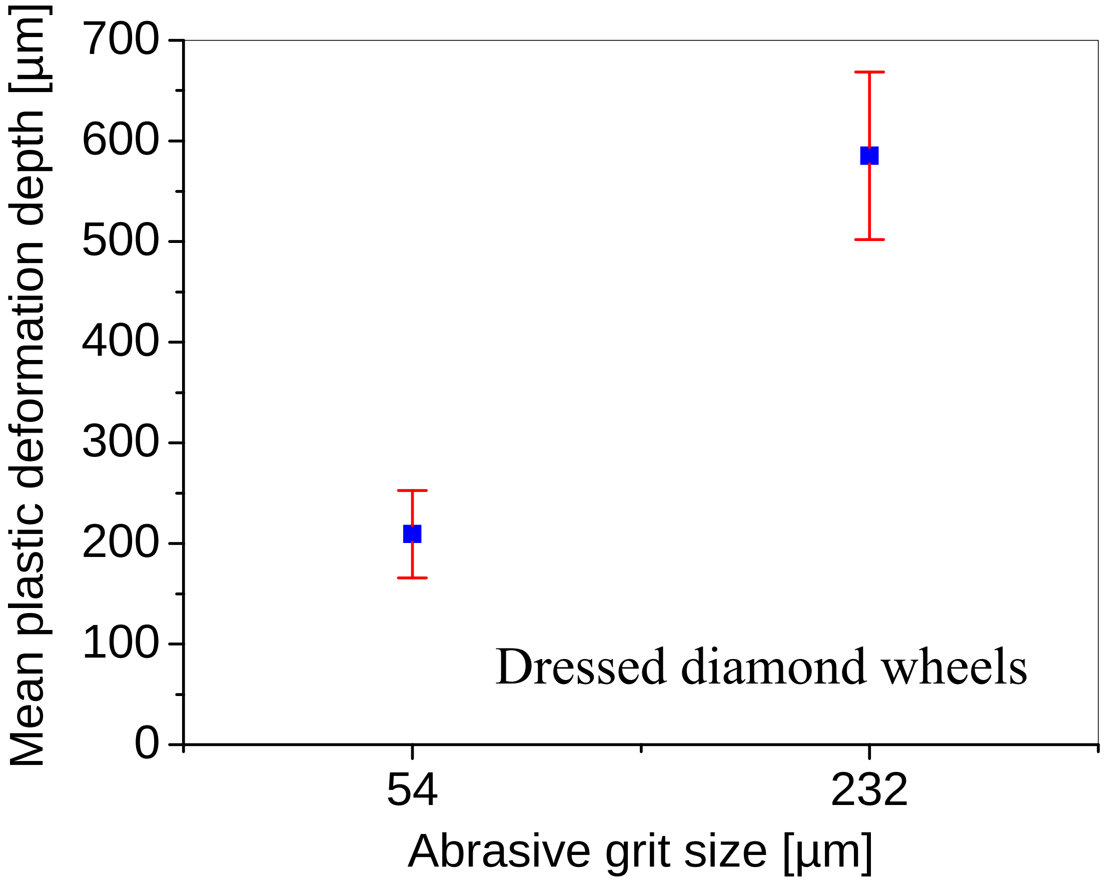
Truing wheel



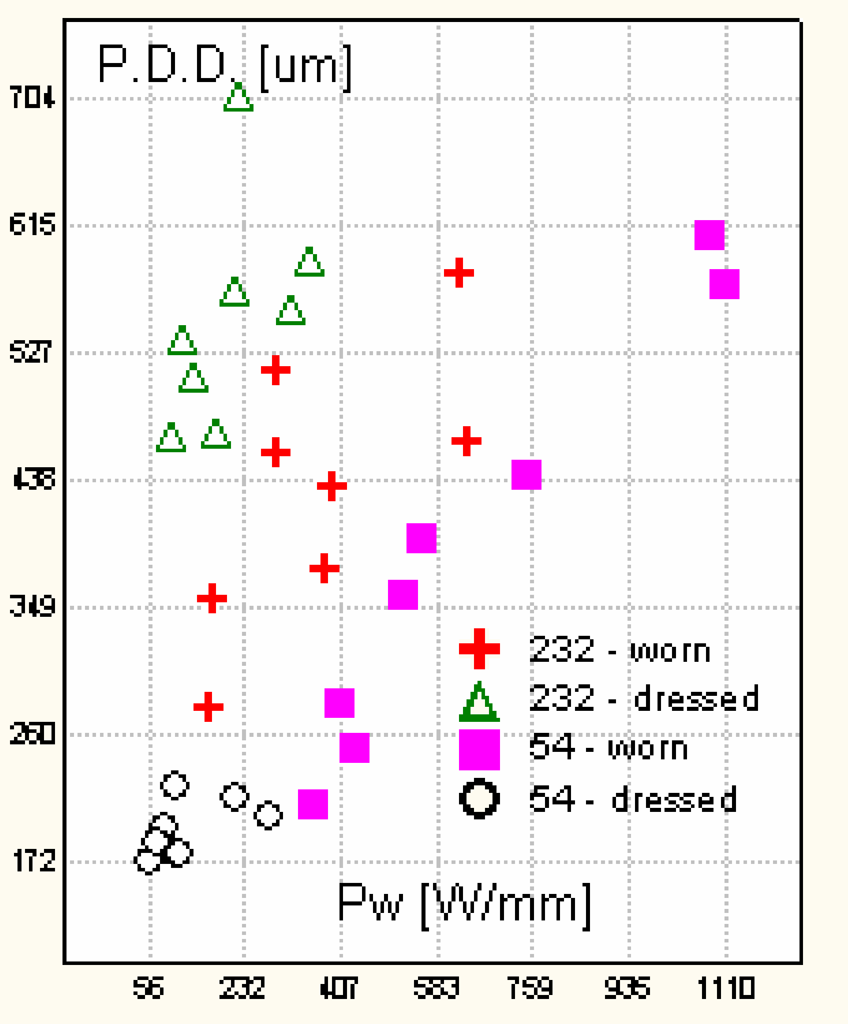
Dressing Stick

- Truing:
  - Gives true shape to wheel
  - Exposes new abrasives
  - Variables
    - Traverse feed rate
    - Depth of cut
    - Wheel type
    - Truing device
    - Material removed
    - Coolant
- Dressing:
  - Exposes new abrasives
  - Sharpens abrasive attack face
  - Variables
    - Plunge feed rate
    - Dressing type
    - Material removed
    - Coolant

Plastic Deformation Depth: Grit Size Effect



Plastic Deformation Depth: Summary



Conclusions

- PD determination technique
  - Useful and practical technique to assess depth of PD
  - Plane fitting method of PD determination is robust w.r.t. surface finishing and gives an average value of PD depth
  - Contour plot method allows the determination of PD depth variability with respect to grain morphology and lamellae orientation

Plastic deformation depth

  - Strongly dependent on grit size for dressed wheel
  - For worn wheels it is not always true that the smaller the grit the lower the damage

- Ongoing research
  - Residual stress measurements
  - Crystal plasticity + FEA modeling

Wheel Conditioning

<table>
<tr><th rowspan="3"></th><th colspan="5">Free wheel / non-collinear axis (7°) truing with coolant</th></tr>
<tr><th rowspan="2">Wheel</th><th colspan="2">Rough truing conditions</th><th colspan="2">Finish truing conditions</th></tr>
<tr><th>Downfeed</th><th>Crossfeed</th><th>Downfeed</th><th>Crossfeed</th></tr>
<tr><td>LB</td><td rowspan="2">75mm D
25mm W
37C60-MVK
Silicon carbide</td><td rowspan="4">20 μm pass
0.3 mm total</td><td rowspan="3">110 cm/min
0.9 mm/rev.</td><td rowspan="4">5 μm pass
0.03 mm total</td><td rowspan="3">75 cm/min
0.6 mm/rev.</td></tr>
<tr><td>LA</td></tr>
<tr><td>SB</td><td rowspan="2">75mm D
25mm W
38A60-MVBE
Aluminum oxide</td></tr>
<tr><td>SA</td><td>55 cm/min
0.45 mm/rev.</td><td>37 cm/min
0.3 mm/rev.</td></tr>
</table>

Wheel Conditioning

	Dry Plunge Dressing	
	Stick	Conditions
LB	**38A120 – IVBE 25 mm x 25 mm**	plunge rate: 40 mm/min total removed: 6.5 cm^3
LA		
SB	**38A 220 –HVBE 25 mm x 25 mm**	
SA		