



# MANHIRP

Integrating Process Controls with Manufacturing to  
Produce High Integrity Rotating Parts for Modern  
Gas Turbines

Presentation to RISC/RoMan

19<sup>th</sup> January 2005

Richard Corran

Email: [Richard.Corran@rolls-royce.com](mailto:Richard.Corran@rolls-royce.com)

Tel: (+44) 1332 764305

## Description of work in last year



- Creation, detection and testing of anomalies (1<sup>st</sup> presentation)
  - Holmaking
  - Turning
  - Broaching
    - All on two materials, Inco 718 & Ti 6/4
- **Developments in NDI (2<sup>nd</sup> presentation)**
- Developments in process monitoring (3<sup>rd</sup> presentation)

# Identification of near term NDI techniques



## WP3: Identification of "near term NDI-methods" to be adapted and NDI development

Status: Sept 15 04

Current NDI   Near Term NDI   NDI Development

Mfg-method / Material	Type of anomaly to be provoked 1)	Description of potential NDI method(s) 2)	Planned date for test blocks to be ready for inspection trials	Potential partner/subcontractor for NDI-technique	Result(s) if available
Hole making/Titanium	Overheating	EC (VAC-Method)	Oct 04	VAC/Uppsala	EC can see anomaly
Hole making/Titanium	Overheating	BEA + laser scanning image evaluation system	Done	LTC (Laser Techniques Co.)	feasible
Hole making/Titanium	Smearing of parent material	laser scanning image evaluation system	Done	LTC (Laser Techniques Co.)	feasible
Hole making/Titanium	Smearing of parent material	EC (rotating probe (with o-scan presentation?))	?	SNECMA / Magdeburg	Very difficult to achieve due to that smearing and amorphous layer is produced at the same time.
Hole making/Titanium	Inclusion of foreign material (tungsten carbide, tool tip)	EC (rotating probe (with o-scan presentation?))	?	SNECMA	It has not been possible to do these trials at this point.
Hole making/Titanium	Inclusion of foreign material (tungsten carbide, tool tip)	Multy frequency-EC-Technique	?	Magdeb.	feasible, quantifiable

Last update  
Sept 17  
-  
to be repeated

# Identification of near term techniques (continued)



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Hole making/Nickel	Incl. of foreign material e.g. from tool (tungsten carbide,)	EC (rotating probe (with o-scan presentation?))	May 04 (1 TB available)	SNECMA	feasible, quantifiable tbd
Hole making/Nickel	Overheating low/high oxidation	EC (VAC-Method)	Done	VAC/Uppsala	More trials have to be done.
Hole making/Nickel	Overheating low/high oxidation	EC (rotating probe)	Feb 04	Magdeburg	?
Hole making/Nickel	Smearing of parent material	Eddy Current rotating probe	July 03	Magdeburg/SNECMA	too small for NDI
Turning/Titanium	Inclusion of tungsten carbide, from tool tip	Eddy Current including multy frequency	more TB Nov 04	Magdeburg	quantifiable tbd
Turning/Titanium	Inclusion of tungsten carbide, from tool tip	MPI <b>New!</b>	more TB Nov 04	MTU	quantifiable hit/miss-type tbd
Turning/Titanium	Inclusion of tungsten carbide, from tool tip	Magnetometric method	more TB Nov 04	Hinken (Magdeburg)	quantifiable tbd
Turning/Titanium	residual deformation & adiabatic shear bands from tool breakage after rework	Eddy Current "normal" & signal enhancement	Jan 04	MTU / Magdeburg / Uppsala	very low signals, practicability questionabl
Turning/Titanium	Smearing of parent material	Aided visual inspection	March 03	MTU	quantifiable hit/miss-type tbd
Turning/Titanium	Smearing of parent material	<del>Eddy Current including multy frequency method and signal analysis</del>	March 03	Magdeburg, Uppsala	normal EC due to lift off hit/miss-type
Turning/Titanium	Smearing of foreign material e.g. from tool fixture	BEA (one use of TB only)	Oct 03	MTU	just hit/miss
Turning/Nickel	Overheating	Eddy Current	in preparation	Magdeburg / SNECMA	

Last update  
Sept 17  
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to be repeated

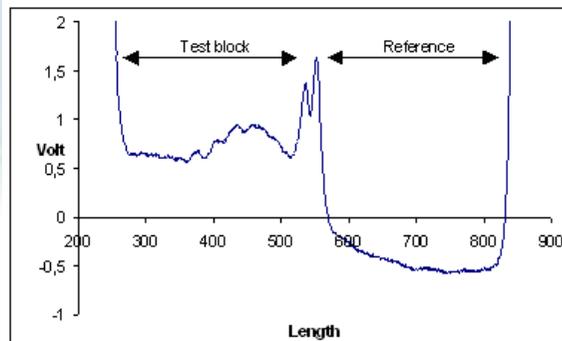
# Identification of near term techniques (continued)



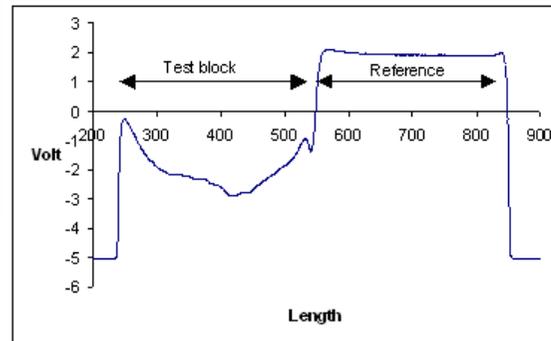
WP3: Identification of "near term NDI-methods" to be adapted and NDI development					
Status: Sept 15 04					
Mfg-metod / Material	Type of anomaly to be provoked 1)	Description of potential NDI method(s) 2)	Planned date for test blocks to be ready for inspection trials	Potential partner/subcontractor for NDI-technique	Result(s) if available
Broaching/Titanium	Flaking	Surface acoustic wave techniques	?	Uni of Nottingham	?
Broaching/Titanium	Cracking	EC Array / Eddy Current including multi frequency method and signal analysis	?	RD-Tech, Magdeburg, Uppsala	?
Broaching/Titanium	Score/scratches/cracking	BEA, FPI	?	R-R	?
Broaching/Titanium	Smearing of parent material	Eddy Current including multi frequency method and signal analysis	?	Magdeburg, Uppsala	?
Broaching/Nickel	Laps	High resolution Eddy Current	third group of test blocks analysis on going	Magdeburg	Partial results
Broaching/Nickel	Laps	Aided visual inspection	third group of test blocks analysis on going	ITP	
Broaching/Nickel	Plucking	High resolution Eddy Current	third group of test blocks analysis on going	Magdeburg	Partial results
Broaching/Nickel	Plucking	Aided visual inspection	third group of test blocks analysis on going	ITP	
Broaching/Nickel	Cracks	FPI / Eddy Current	?	ITP/Magdeburg	?
Broaching/Nickel	Inclusions of Foreign Material (Tool Tip)	MPI <b>New!</b>	?	MTU	
Broaching/Nickel	Inclusions of Foreign Material (Tool Tip)	Eddy Current	?	Magdeburg	?
Broaching/Nickel	Smearing of parent material	Aided visual inspection	third group of test blocks analysis on going	ITP	Partial results
1) see anomaly experience table		2) see 6M-report page 13			
			<b>u00979:</b> It has not been possible to produce cracks in the material		
				<b>u00979:</b> First trial to put not artificially some tool material was not successful	

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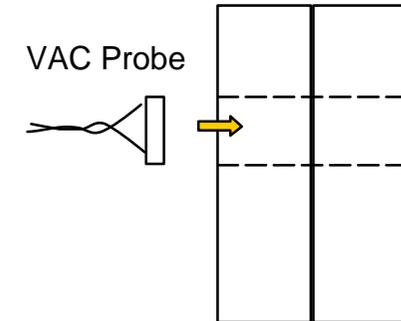
# Inspection of holes in Ti 6/4



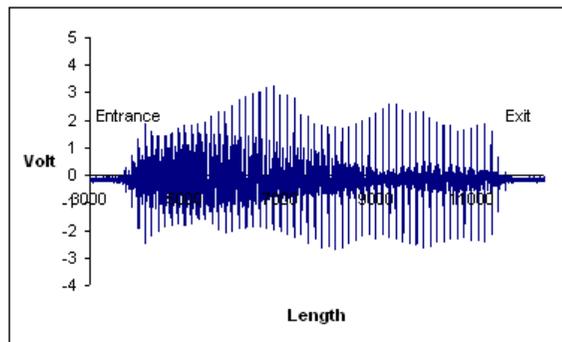
Y component of eddy current signal



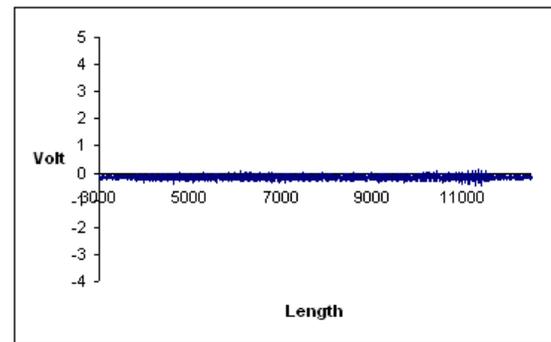
X component of eddy current signal



Test block Reference



Specimen with scratches

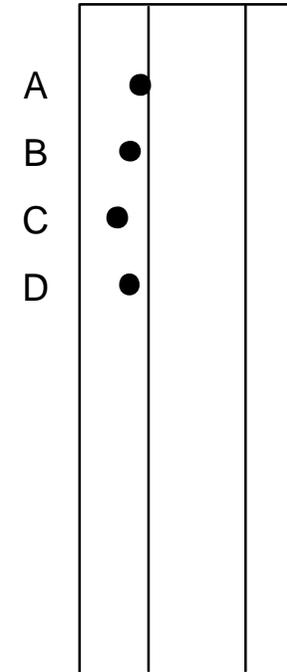
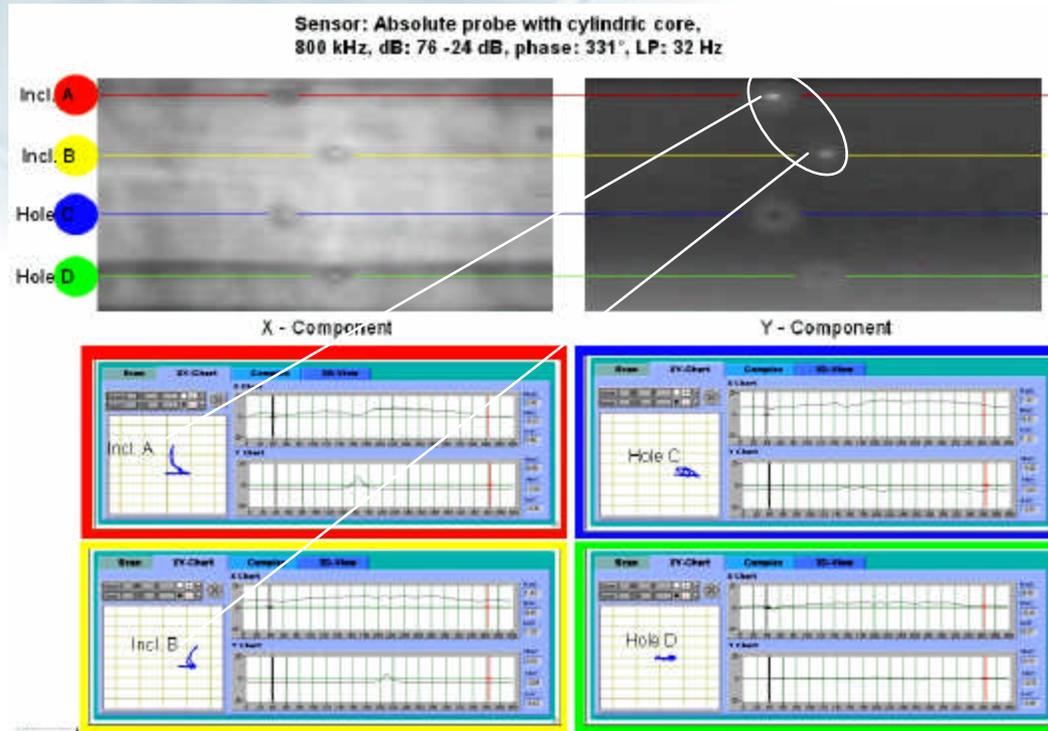


Reference specimen

Scratched specimens  
examined by rotating  
eddy current

- 5 specimens have non-geometric anomalies (e.g. smearing) and 3 have scratches from entry to exit

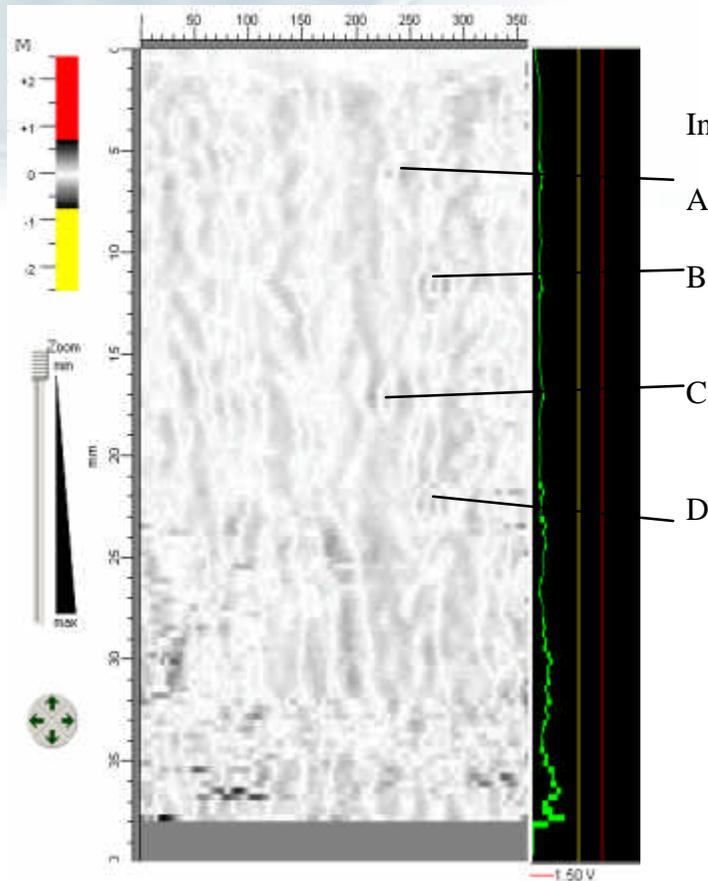
# Tungsten Carbide inclusions from tool breakage in holes



- Eddy current detection of WC inclusions in a hole in titanium.
  - Inclusions A and B are shown in the Y-component c-scan
  - Holes C and D without inclusion are only displayed in the left c-scan of the x-component.

WC particle	Dia., mm.	Depth, mm.	WC incl.
A	0.075	0	Y
B	0.150	0.05	Y
C	0.075	0.10	N
D	0.150	0.05	N

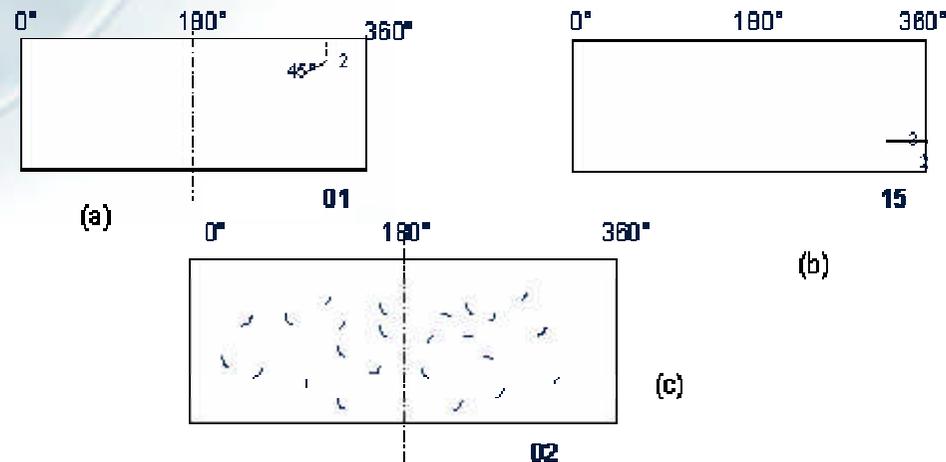
# Conventional E/C inspection of WC inclusions



Indications of :

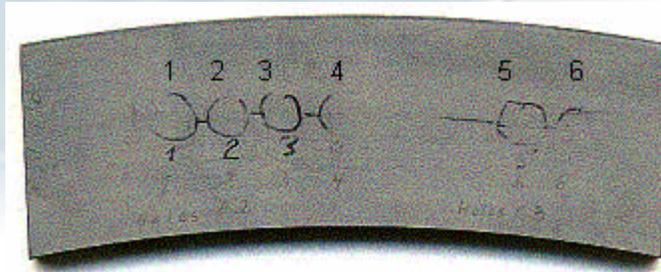
- Eddy current c-scan image performed by SNECMA Lab on the titanium test tube with a standard ET rotating test with c-scan presentation.
- The indications are hardly detected.
- No possibility to separate filled and empty holes due to poor S/N-ratio.

# Inspection of holes in Inco 718

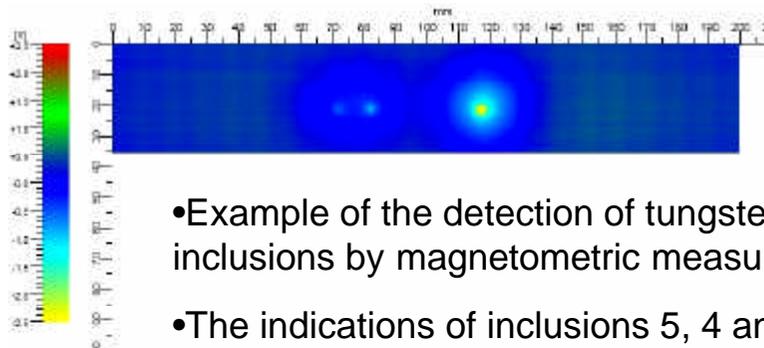


- **FPI typical indications (a) & (b): scores and scratches?, (c) smearing?**
  - The multitude indications as (c) can be related to smearing but the detection is not reproducible and need to be performed by a technically experienced operator.
- Eddy Current was used with a high-speed differential rotating probe at frequency 2 MHz: no significant indications were revealed by this technique.
- This NDI overview shows that the defects are too small and/or too non geometrical to be detected by the available NDI.
- For the next LCF sample inspections, FPI will be the only control performed to increase the potential NDI database.

# Turned Surfaces in Ti 6/4



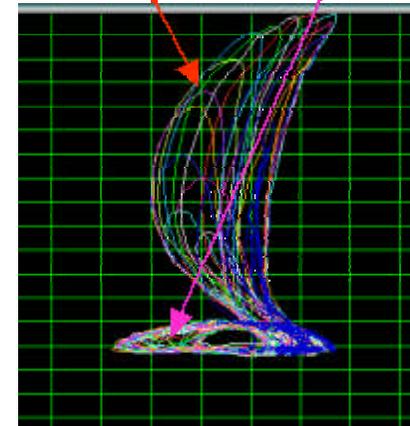
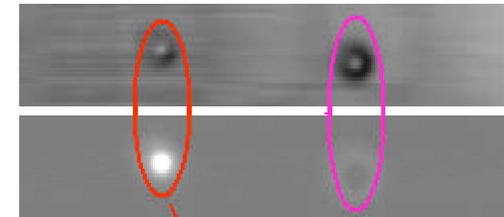
- A test block prepared for the verification of tungsten carbide inclusions by eddy current and/or magnetometric measurement.
- Each number refers to the position of drilled hole (within circle) with or without a WC inclusion



- Example of the detection of tungsten carbide inclusions by magnetometric measurement
- The indications of inclusions 5, 4 and 3 are clearly to be seen, while inclusion 2 is too small to shine up due to its brighter neighbourhood.
- Empty holes are not indicated.

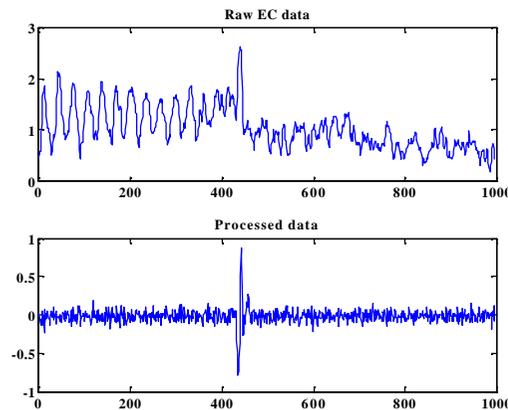
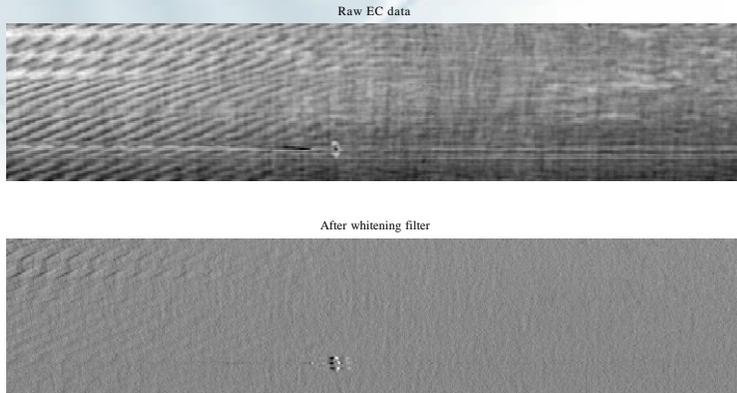
X

Y



- Example for the detection of a tungsten carbide (WC) inclusion.
- A phase shift of about 90° shows the presence of WC.
- In the c-scan Y-image (upper part of image) the difference is clearly shown between a hole with a WC inclusion (left signal, circled in red) and empty hole (right signal).

## Turning of Ti 6/4 – NDI Development – Signal analysis for special anomaly types

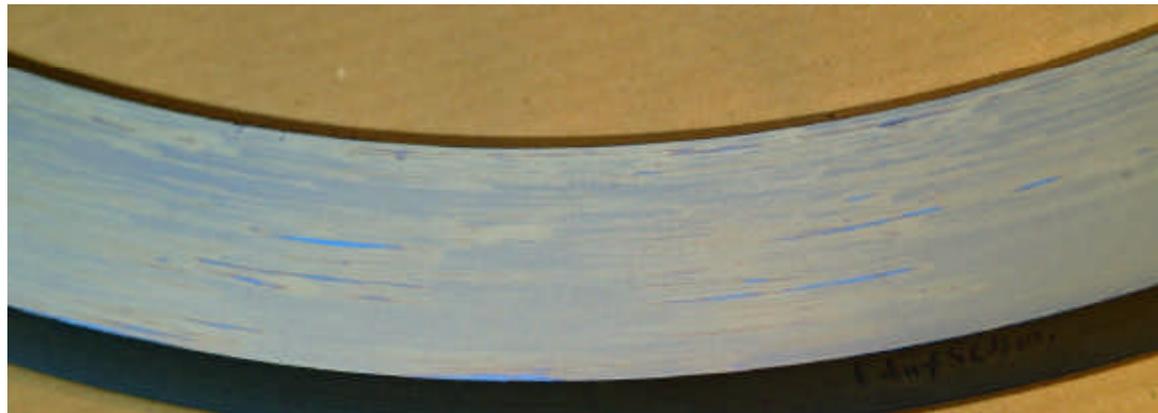


- EC C-Scan of anomaly in Ti ring
  - Raw data (upper)
  - After processing (lower)
- Single EC scan of an anomaly in Ti-ring
  - Raw data (upper)
  - After processing (lower).
- Special process technique of “whitening” filter which performs spectrum equalisation of a stochastic signal
  - Suppresses distinct frequency peaks
  - Enhances frequency intervals where signal has low energy

## Detection of adiabatic shear bands using BEA



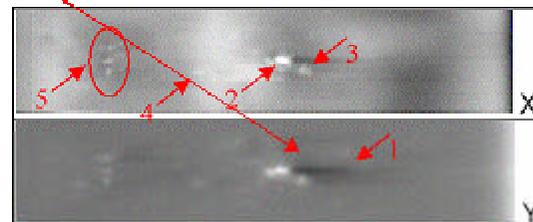
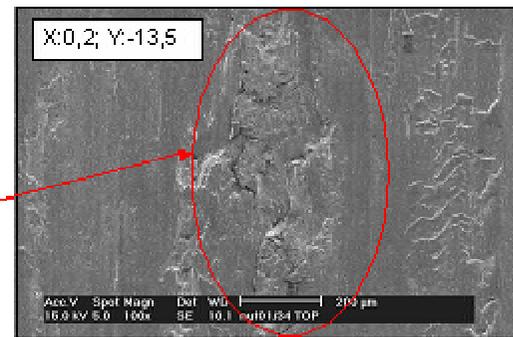
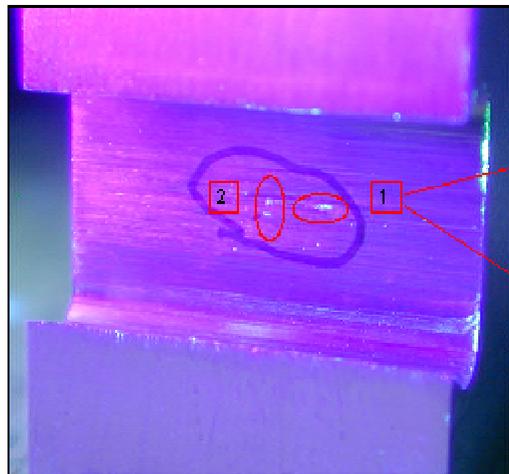
Adiabatic shear bands (arrowed)  
highlighted by BEA



BEA of a turned surface,  
which was deliberately  
contacted by the tool  
fixture during turning. The  
metal distortion produced  
is clearly indicated

# Application of inspection to broached slots in Inco 718

Sample identification	Cutting conditions	Indication number	Defect locations X-Y, mm	Type of damage	Evaluation method		
					SEM	FLP	MFEC
nUT01x34	Coolant OFF Toolwear	1	X=0,2; Y=-13,5	Pluck and laps	Yes	Yes	Yes
		2	X=0,2; Y=-11,5	Smearing and laps	Yes	Yes	Yes
		3	X=0; Y=-12,5	Small plucks	Yes	No	Yes
		4	X=-1,2; Y=-8	Small plucks	Yes	No	Yes
		5	X=0; Y=-3,95	Small pluckings	Yes	No	Yes
		6	X=2,35; Y=-11,5	plucks	Yes	No	Yes



- Typical NDI inspection images showing
  - FPI (left hand side)
  - SEM confirmation (top right)
  - Eddy current results (bottom right)

## Preliminary conclusions about inspection of broached slots in Inco 718



- Detection capability:
  - EC maybe more accurate than FPL for shallow and small groups of plucks.
  - Initially, not possible for parent material smearing detection.
  - No difference in the conductivity but one apparent indication detected.
- Further work on going: ferromagnetic analysis (include some reference point in order to locate the indication more accurately)
- Types of Multi Frequency Eddy current Detector:
  - Hard disk probe: best anomaly images, difficult to handle, the probe has to be in contact with the surface.
  - Absolute transmit receive probe (TR): does not provided as good as images, easier to handle, does not need to be in touch