

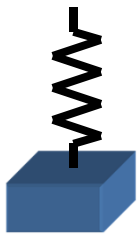
# Process Compensated Resonance Testing

*Vibrant NDT Ltd*  
*Smithfield*  
*Sheffield*  
*S3 7AR*  
*[www.vibrantndt.co.uk](http://www.vibrantndt.co.uk)*

A Partnership between Johnson & Allen Ltd (UK) and Vibrant Corp (US)

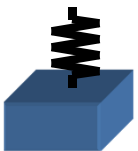
# *Resonant Inspection*

Resonant Inspection correlates directly to components' strength



Resonant Frequencies determined by dimensions and material properties of "whole part".

$$f_r \sim \sqrt{k/m}$$



$f_r$  = Resonant Frequency

$k$  = Stiffness (elastic properties e.g. Young's Modulus)

$m$  = Mass (dimensions, density)



## *ASTM Standards*

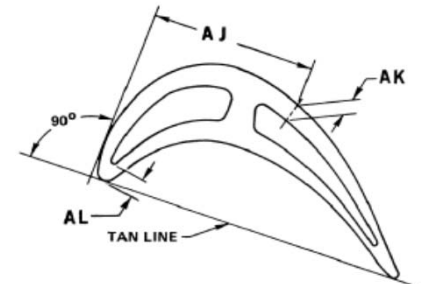
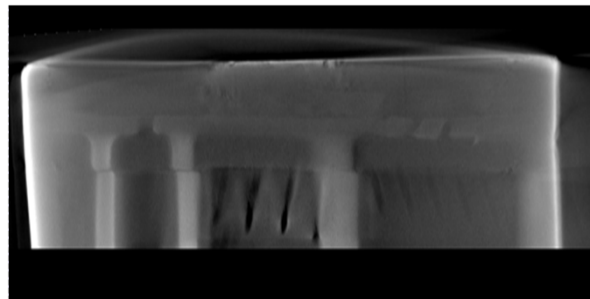
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- ASTM E2001-08 Standard Guide for Resonant Ultrasound Spectroscopy - Outlines capabilities and applications of several resonant inspection methods.
- ASTM Standard Practice E2534-10 - Describes auditable method for successful application of PCRT specifically and in depth.
- FAA Approval for JT8D-219 T1 Blades

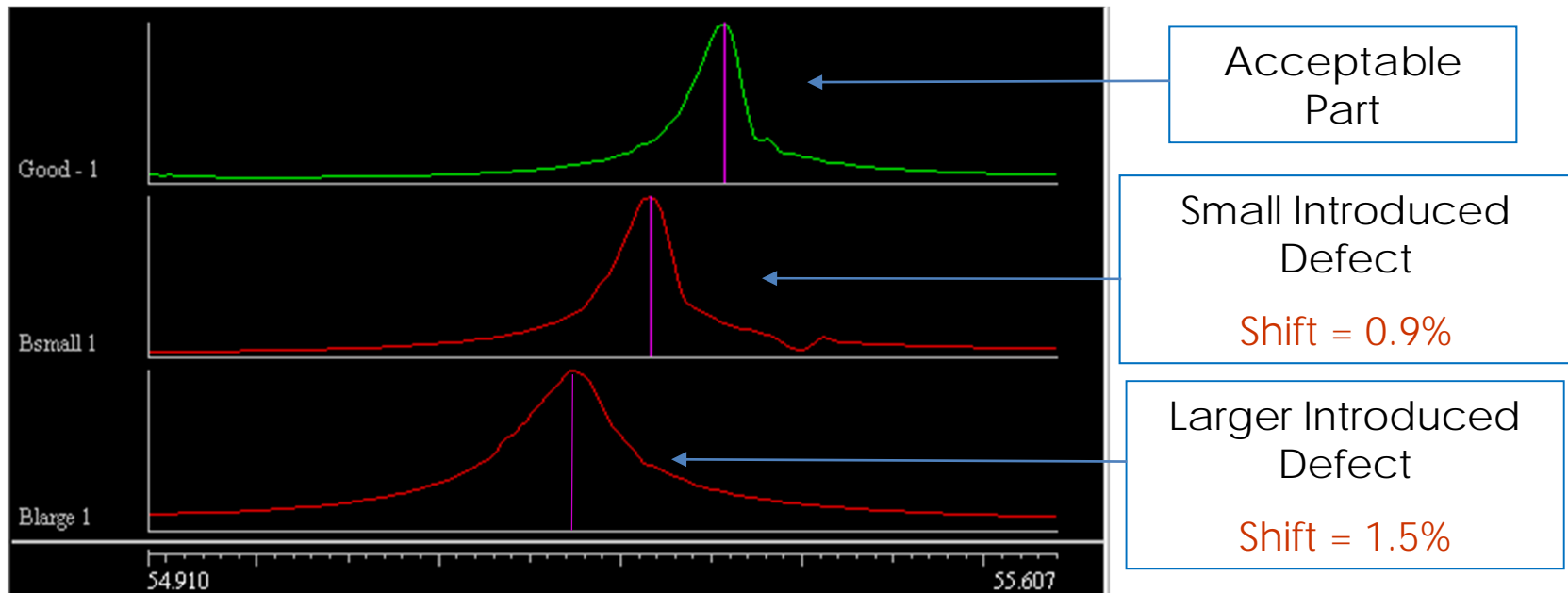


## *What Does RUS Detect?*

- Changes in stiffness due to discontinuities, geometry variation and manufacturing defects.
- Differences in modulus resulting from wide spread material property variations.
- Variations in modulus resulting from microstructure changes such as gamma prime solutioning, rafting, spheroidization etc.

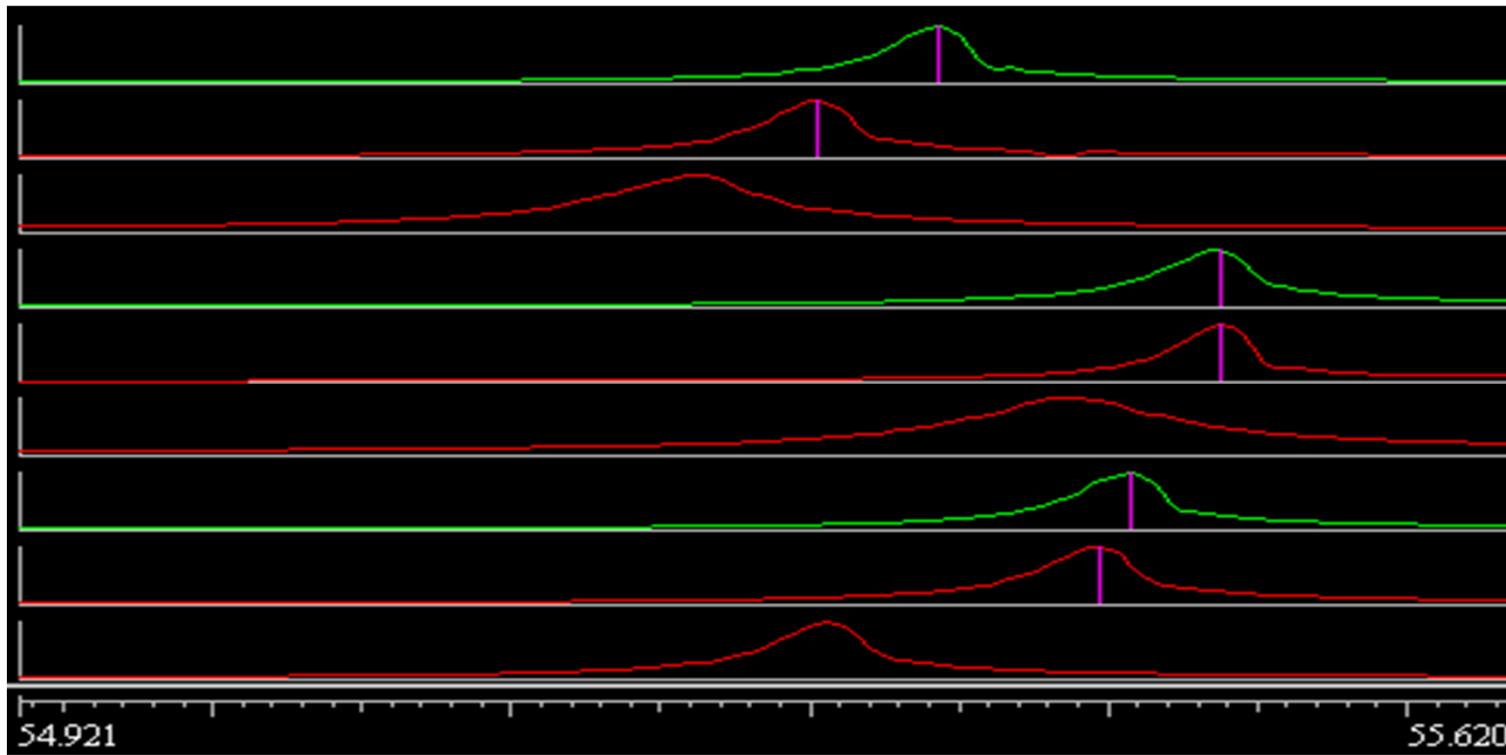


## Defect Detection With RUS



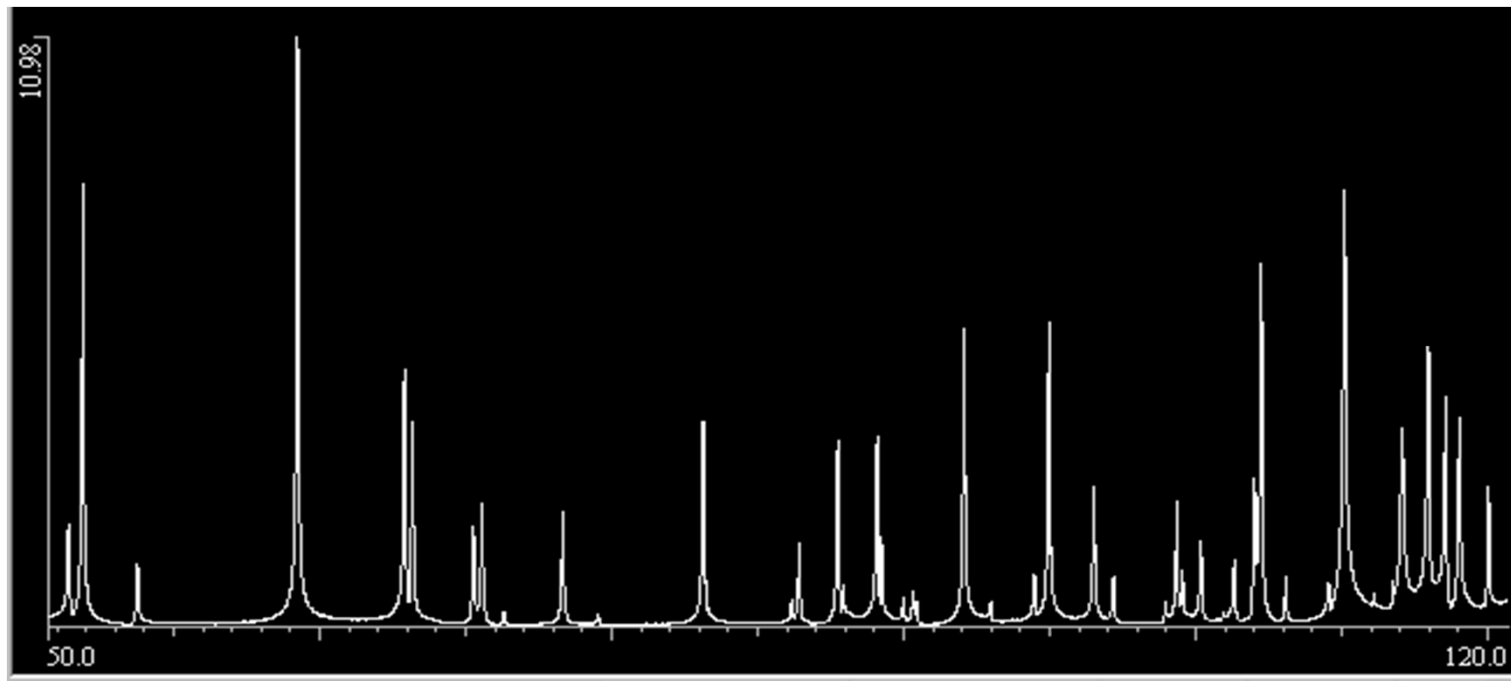
A structural defect reduces the stiffness of the part and causes a proportional shift in the resonant frequency.

## *Defect Masking*

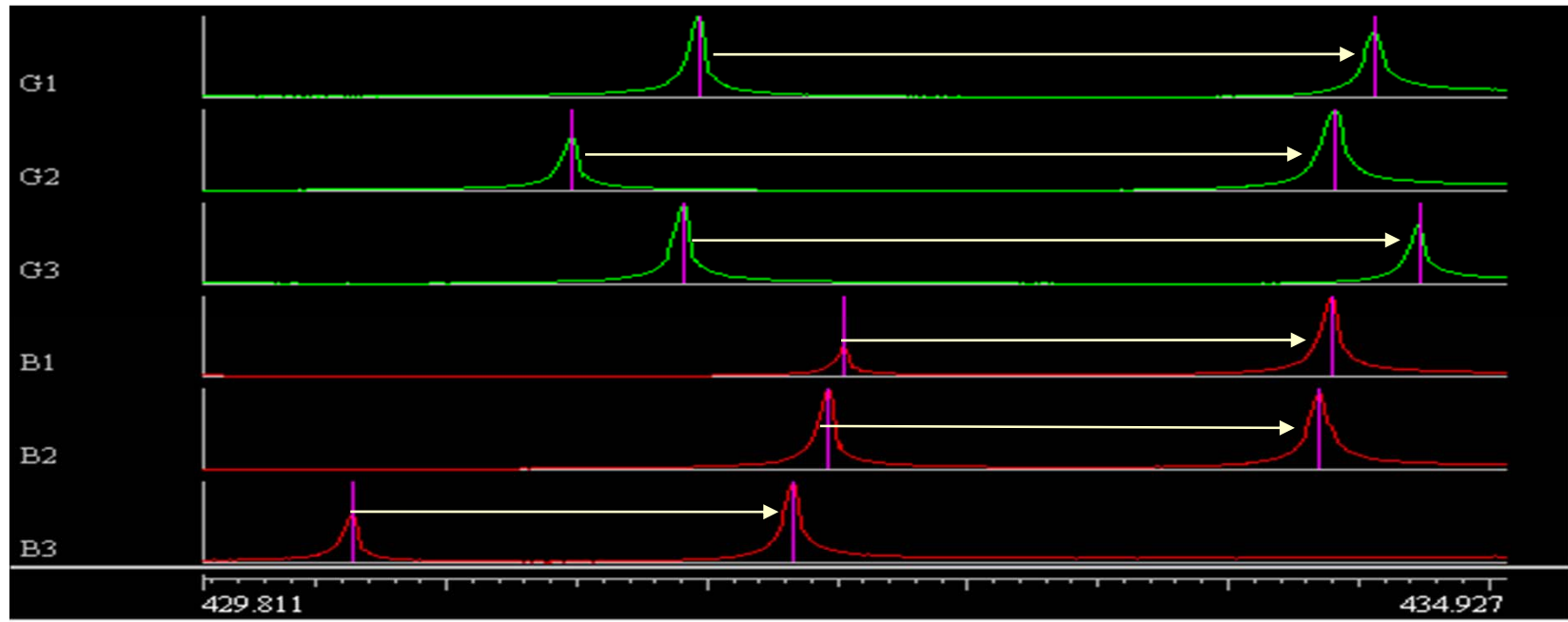


Simple resonance analysis is insufficient for defect detection since unacceptable and acceptable patterns are interlaced.

## *PCRT Spectra*



The PCRT System applies pattern recognition to the entire spectra of the part to determine which parts are acceptable and which are defective.



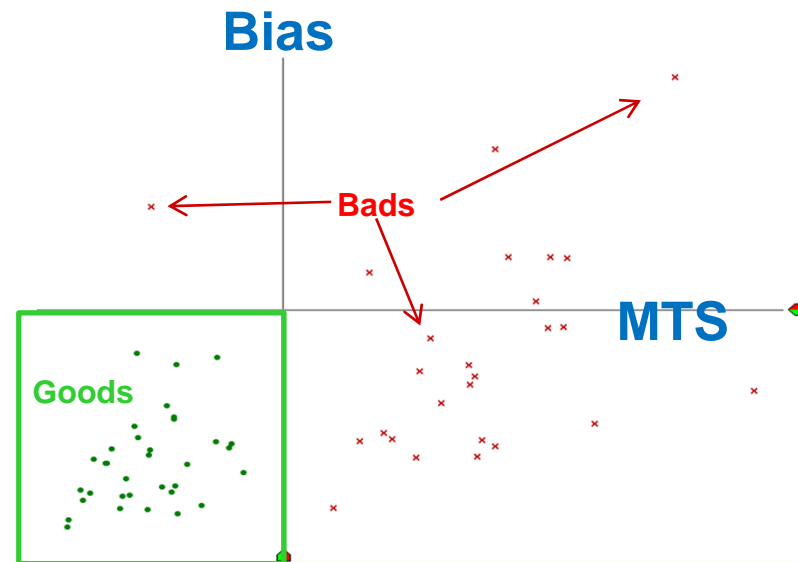
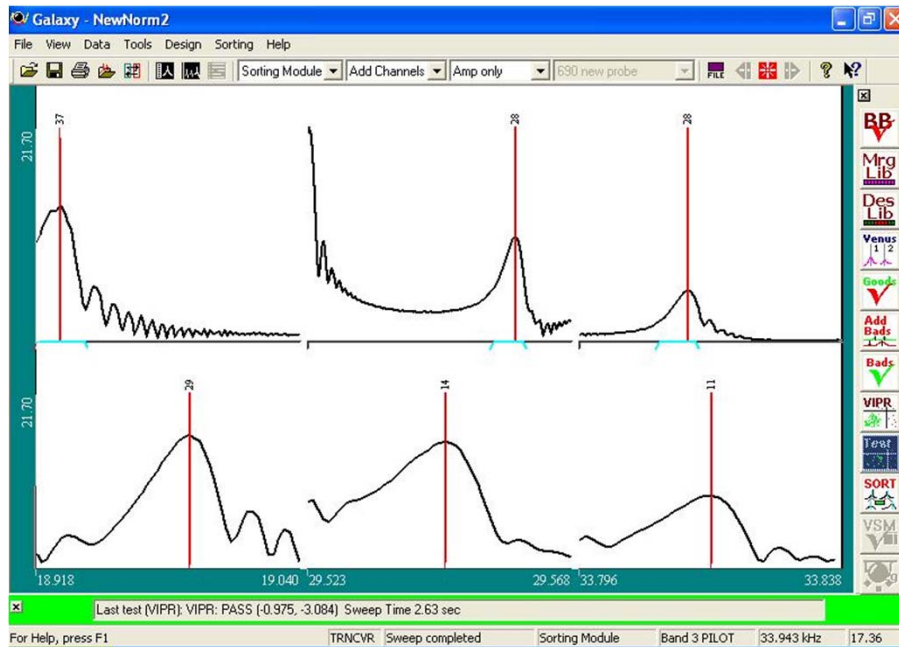
- ✓ All good blades have a peak separation of  $2,600 \text{ Hz} \pm 200 \text{ Hz}$
- ✓ Bad blades have a peak separation of less than  $2,000 \text{ Hz}$



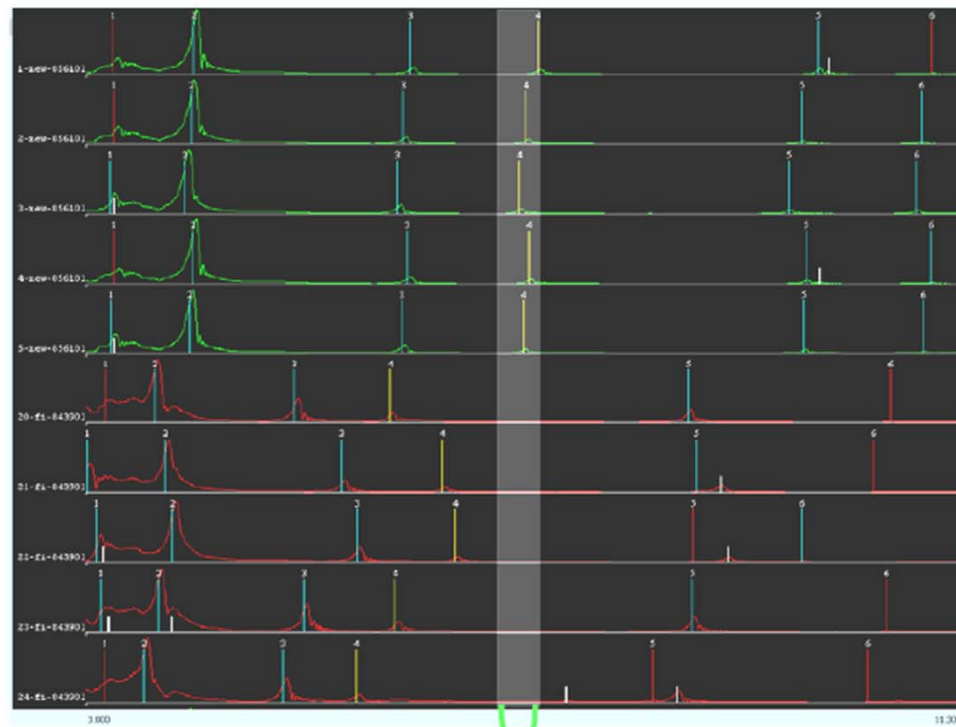


## *Two Items Critical to PCRT*

- Both MTS and Bias tests can get smarter over time as additional confirmed "goods" and "bads" are added to the database.
- MTS scores also serve as a near real time measure of process capability in the manufacturing environment.



# Simple Pattern Recognition



Frequency range of good population

Good blades

Cracked blades



✓ All good blades have a peak in the narrow gray band.

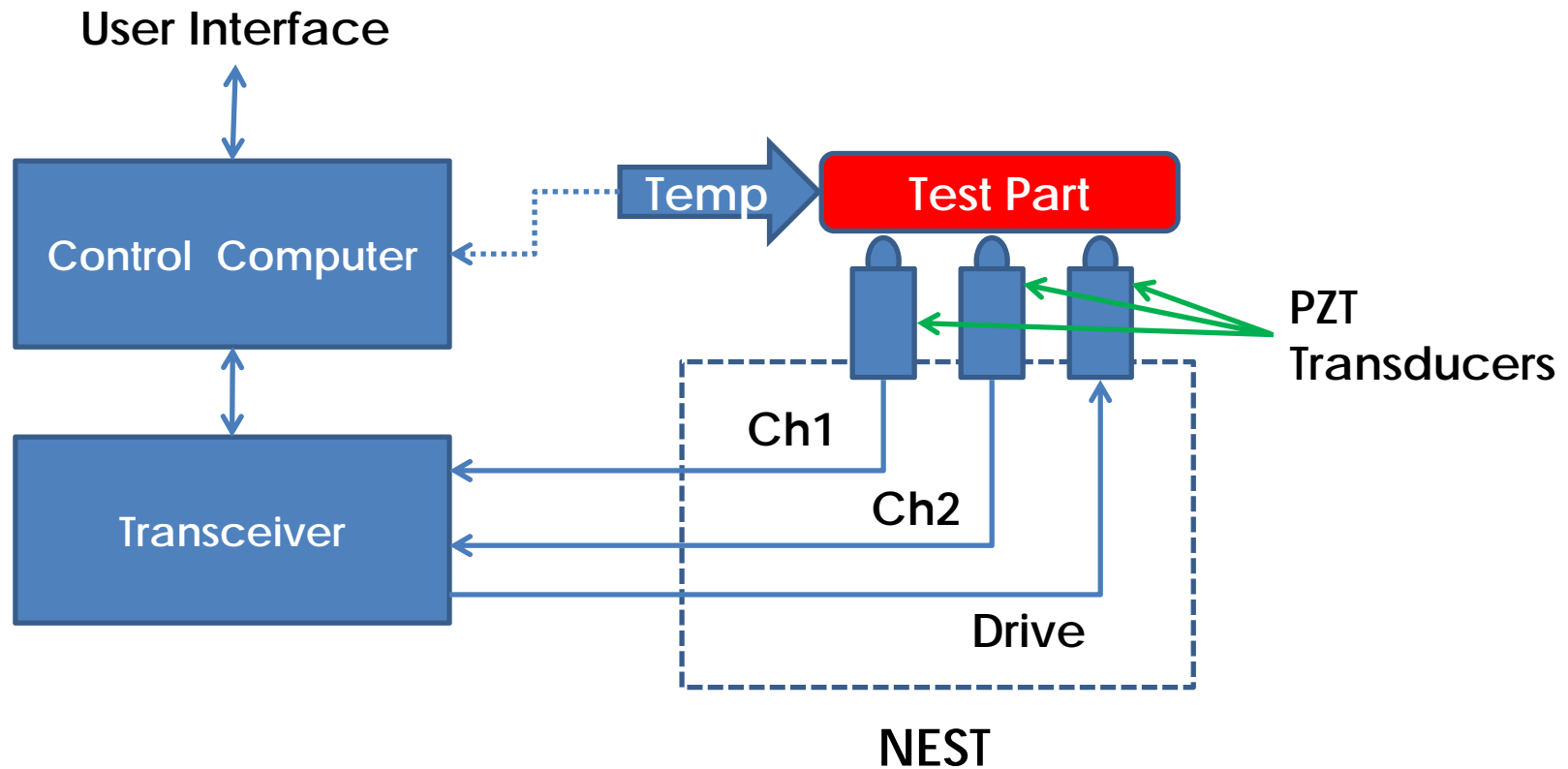
✓ Non-cracked blades have a peak in the narrow gray band.



## *PCRT System Components*

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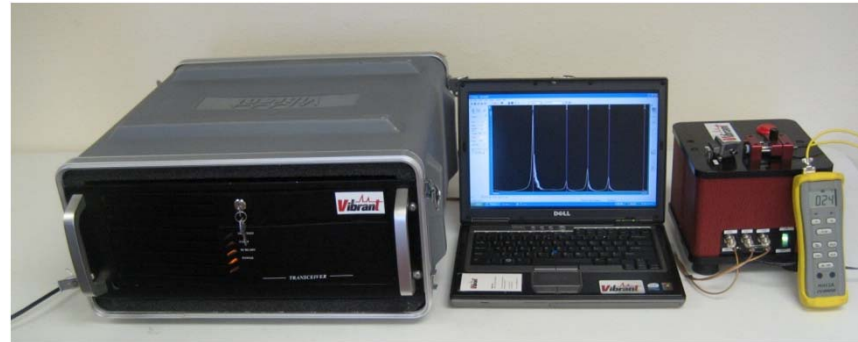
- PCRT System Hardware
  - Simple part interface, PZT transducers.
  - Precision spectrum analyzer & signal generator.
  
- PCRT System Software
  - PC computing power.
  - Statistical analysis with the Mahalanobis-Taguchi System (MTS).
  - Vibrational pattern recognition algorithms (VIPR).
  - Digital storage of spectra.



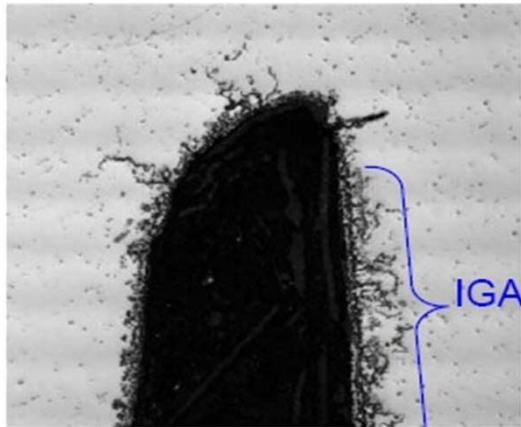


## *Scalable Systems to Meet Your Needs*

- Low volume system
  - Hand loaded.
  - Tests up to 2-3 parts per minute.
  
- High volume system
  - Fully automated.
  - Tests up to 30 parts per minute.



# Defect Examples

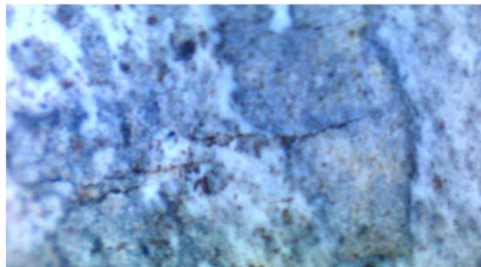


Inter-granular attack

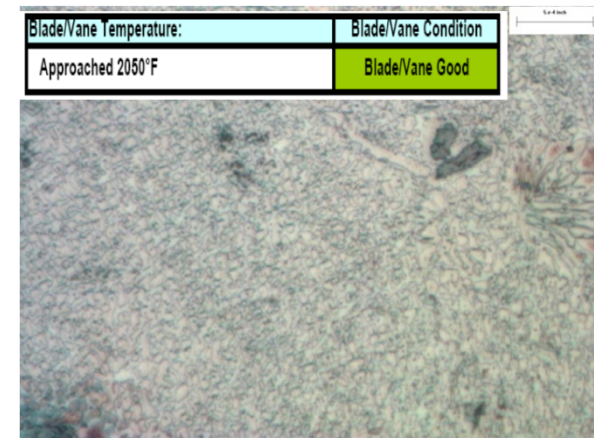
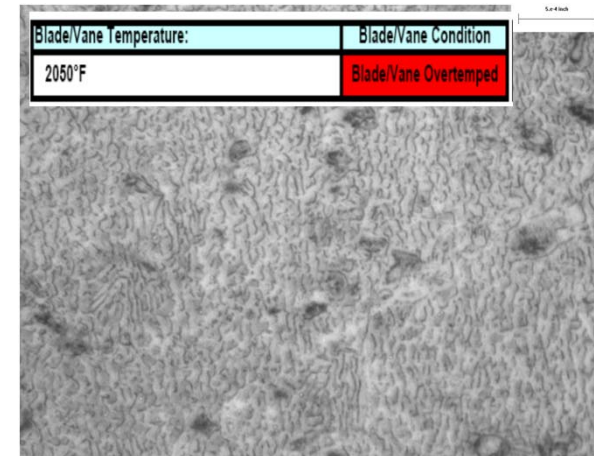
- ✓ Heat treatment errors
- ✓ Solutioning errors
- ✓ Core shift & integrity
- ✓ Material loss
- ✓ Hidden discontinuities
- ✓ Material property variation



Thin wall

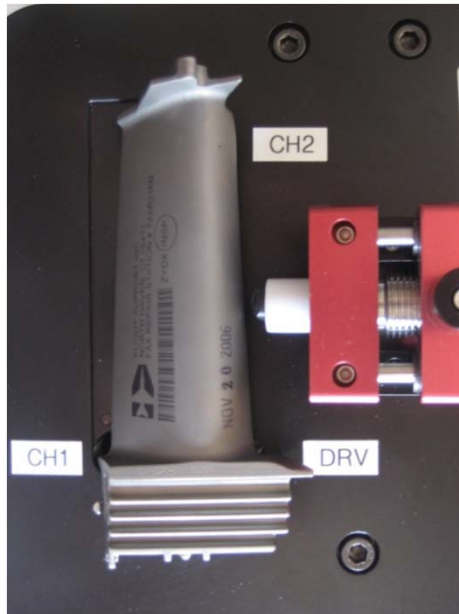


Cracks

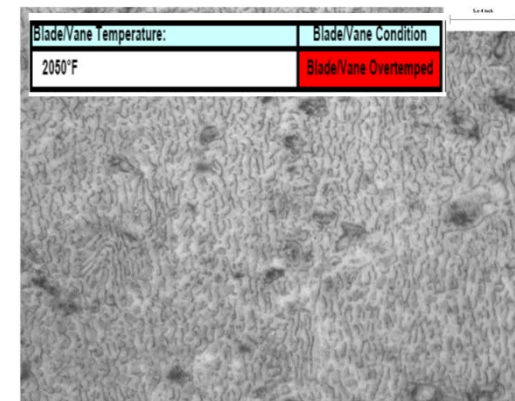




## *JT8D 1<sup>st</sup> Stage Turbine Blades*

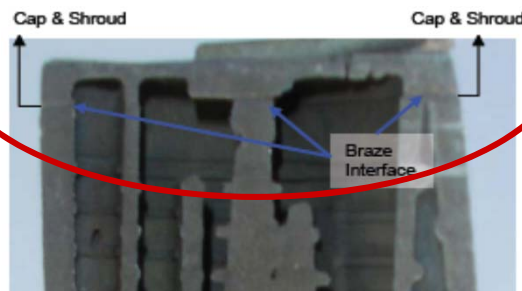
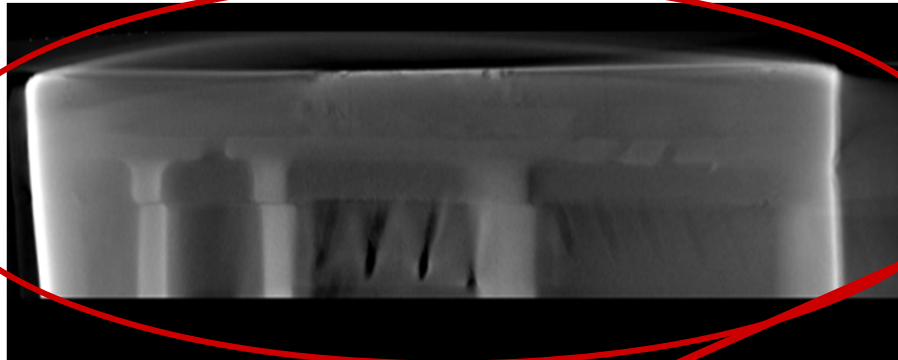


- Core shift in casting produces thin wall.
- Over-temp in service causes gamma prime formations.
- PCRT detects cracks, overheat, inter-granular attack and thin walls.





## *CF6 80 1<sup>st</sup> Stage Turbine Blades*



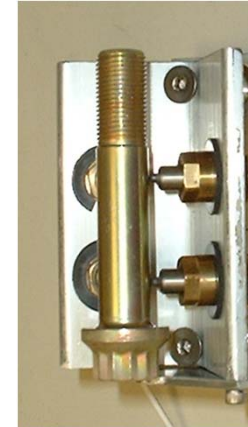
- Manufacturing defect leads to premature failure.
- Defective braze joint.
- PCRT detects insufficient braze and misalignment.



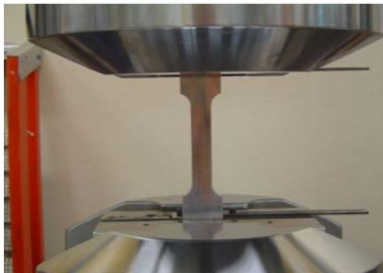




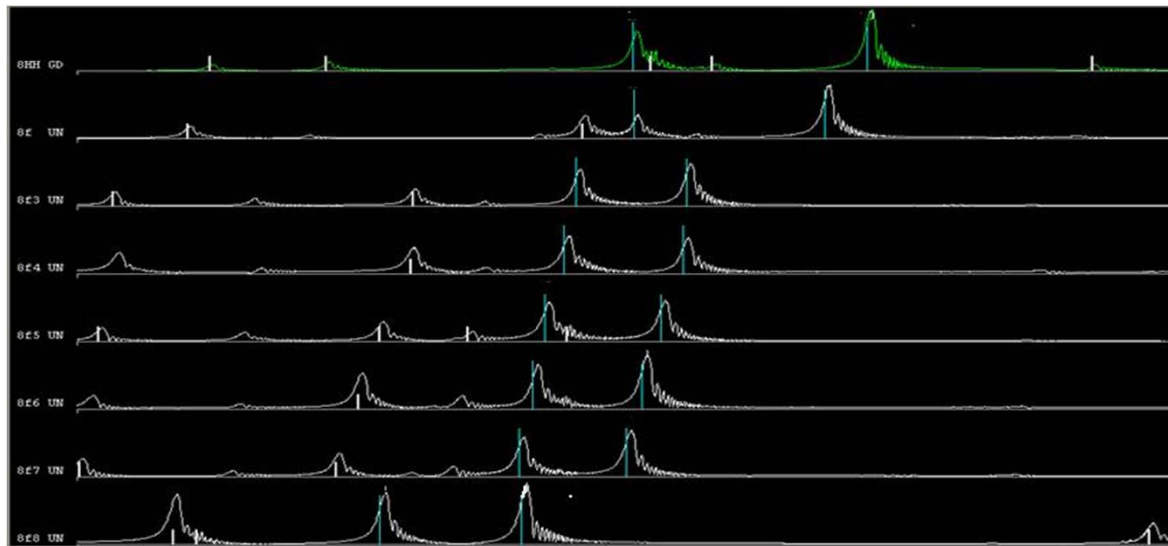
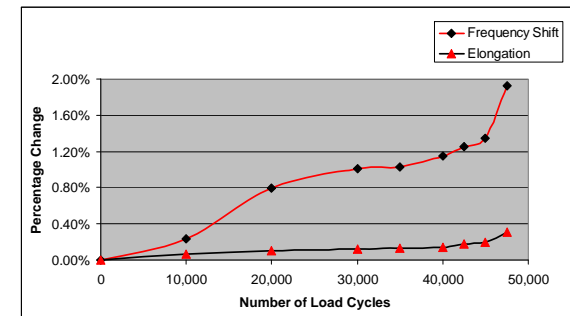
# *Aerospace Applications*



# In-Service Tracking



Changes in resonance of a part over time correlate well to the accumulation of fatigue and damage *BEFORE* crack initiation.



New condition

10,000 cycles

20,000 cycles

30,000 cycles

35,000 cycles

40,000 cycles

42,500 cycles

← Onset of cracking  
45,000 cycles

Resonances in the 108 kHz band



# Life-of-Part Integrity Surveillance

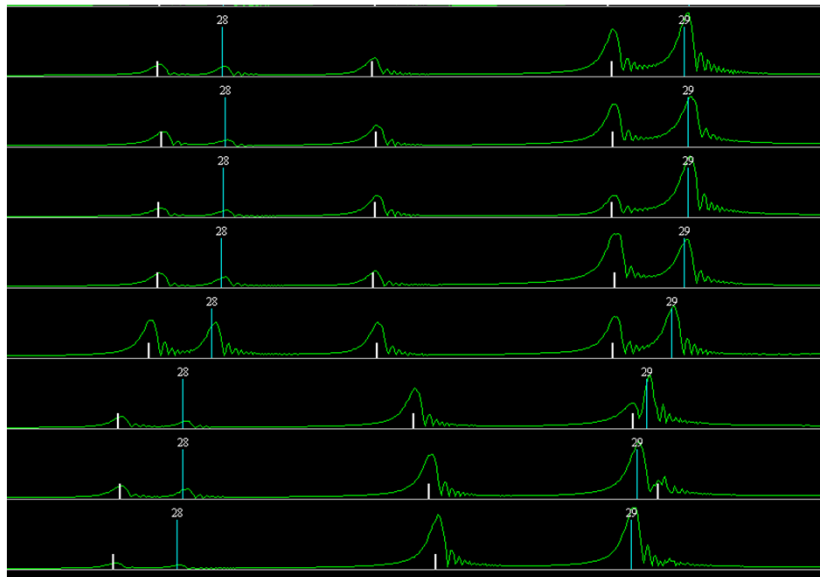
~300 Cycles



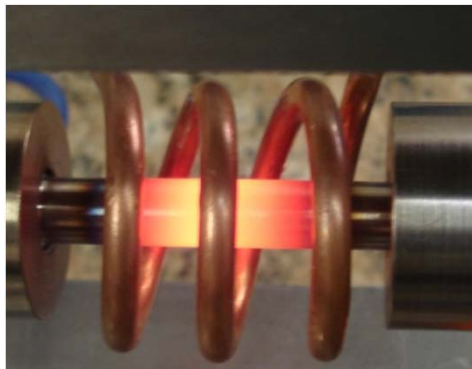
~500 Cycles



Crack  
Initiation →



Rene 80 hollow  
coupon in low cycle  
thermo-mechanical  
fatigue.



- Tracking resonance changes by serial # over time eliminates "noise" of manufacturing variation.
- Offers OEM's real world data on part performance over time.
- Offers maintainers a tool to predict remaining life of individual components.
- Provides early warning of manufacturing or field performance issues.



## *PCRT's Strengths*

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- Rigid, Hard Components.
- Characterising Mature, Well-Controlled Manufacturing Processes.
- Sorting for Structural Integrity.
- Single, Whole Body Test for Multiple Defect Sources.
- Reduction of Operator Interpretation Error.
- Digital Historical Record of Resonant Spectra for Life-of-Part Surveillance.



## *Summary*

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- PCRT is NDT based on structural integrity of the part.
- Pass/Fail testing is fast and requires no operator interpretation.
- PCRT is proven for aerospace applications.
- PCRT is green, requiring no chemicals and little or no part cleaning.