

19th SYMPOSIUM ON INDUSTRIAL APPLICATIONS OF GAS TURBINES



Training Session 8: Gas Turbine Repair Technology

by

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Presented at the 19th Symposium on Industrial Application of Gas Turbines (IAGT)
Banff, Alberta, Canada - October 17-19, 2011

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Why Repair?

- Maintenance after fuel is the main operating cost over the life cycle of a GT
- Spare part replacement and repairs of hot section components represent the major cost portion of all maintenance
- Typically component repairs cost 10% to 30% of the replacement new part cost
- Repairs represent main cost savings opportunity to the customer

What do you get?

- Detailed Non Destructive Inspection of components
- Where applicable destructive analysis and report on sample component to investigate life limiting mechanisms
- Where possible repair of life limiting mechanisms
- Repair of certain critical dimensioned features
- Replacement of protective coatings
- Serviceable components

Gas Turbine Materials

Compressor

Some 300SS
403, 410, 422,
450 Stainless
IN718
Ti64 titanium

Combustor

300SS
Hastelloy-X, RA-33
IN-600, IN-617
Nimonic 75, Nimonic 263
Haynes 230

Compressor

Casings

Grey Cast Iron
Carbon Steel
Aluminum

Turbine Shells

Ductile Cast Iron
Stainless Steel
Nickel Alloy

Compressor

Wheels/Disks

Ni-Cr-MO-V
Forging

Turbine

Wheels/Discs

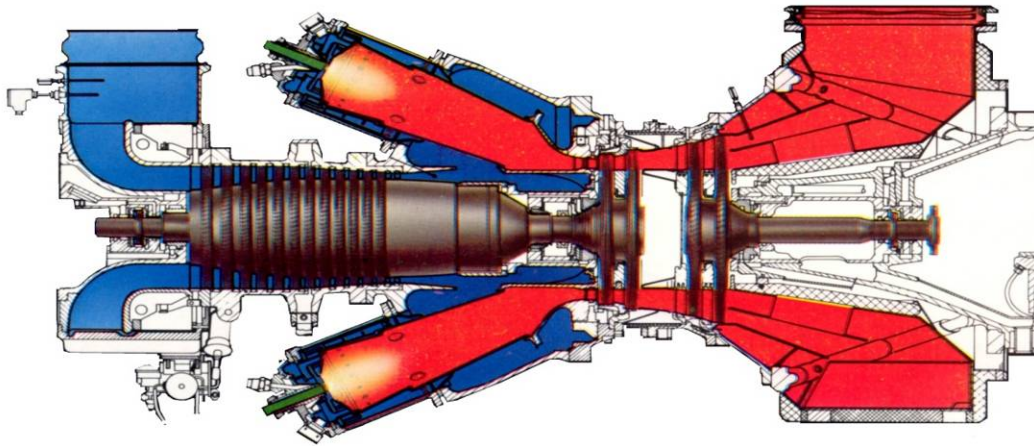
Ni-Cr-MO-V Steel
Cr-Mo-V Forging
12Cr Stainless
Discalloy
A286
IN718

Turbine Rotating

N105, N108, N115, Waspalloy, U-500, U520,
U700, U710, U720, INX750, IN738,
Rene80, GTD111, Mar-M247, Mar-M002,
PWA1483, CMSX4, ReneN5

Turbine Stationary

300SS, 400SS, C242, C1023
N-155, M509, HS-188, L605
X-40, X-45, FSX-414, ECY-768
IN738, R80, GTD222, GTD444



Repair Process

Incoming Inspection

Clean & Strip Coatings

Fluorescent Penetrant Inspection

Geometry Repair

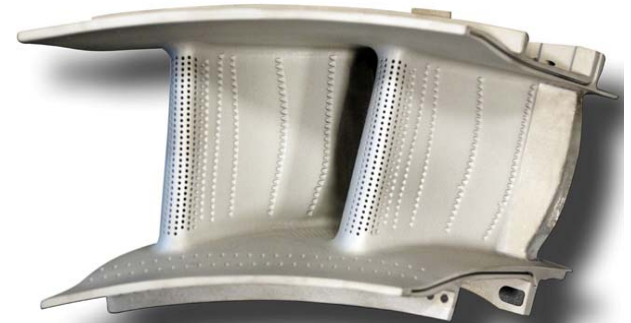
Machine/Finish Geometry

Heat Treatment

Pre-Coating Inspection

Coating

Final Inspection



Incoming Inspection

- Triage
 - Is the component repairable?
 - What is the expected level of repair?
- Solid Blades vs. F-Class Internal Geometry
- Increased reliance on life analysis of blade



Life Analysis

DS Alloy Damage

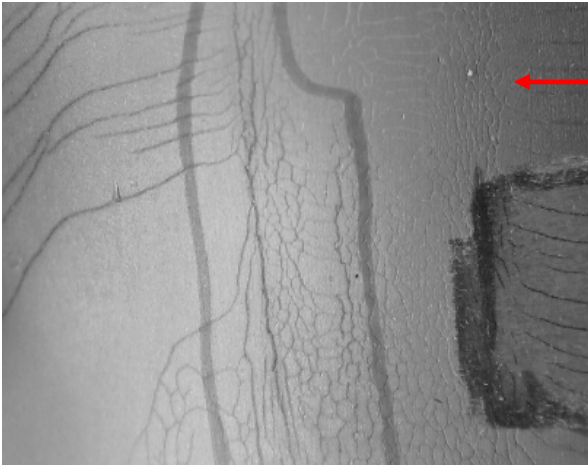
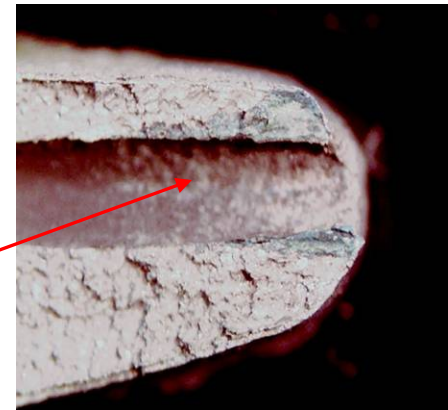
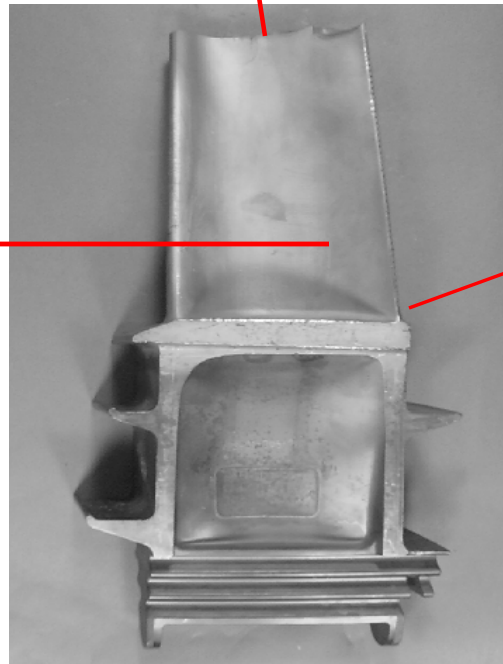
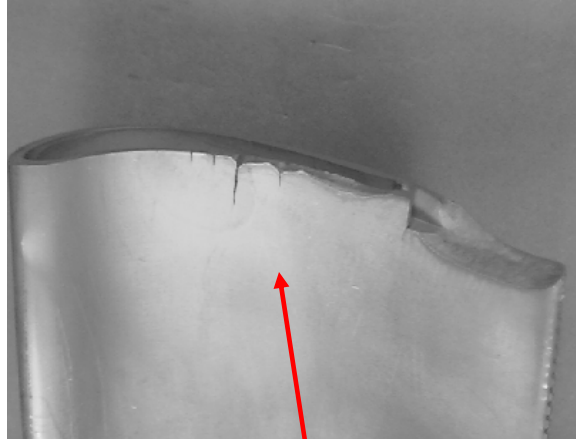
Cracking along DS grain boundaries at tip

Oxidation burning at tip

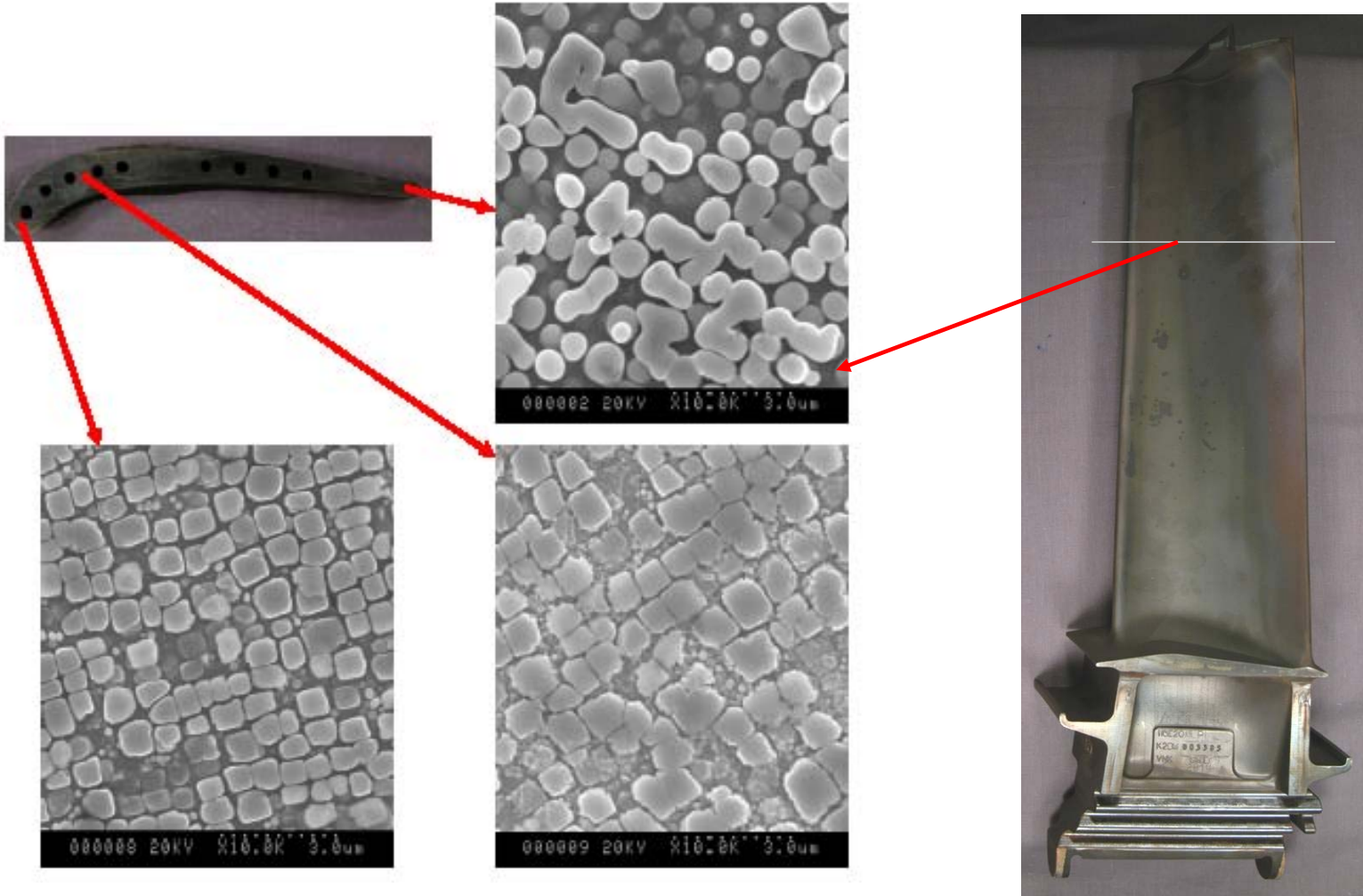
Coating cracks in airfoil

#1 Cooling hole crack

Incomplete internal coating

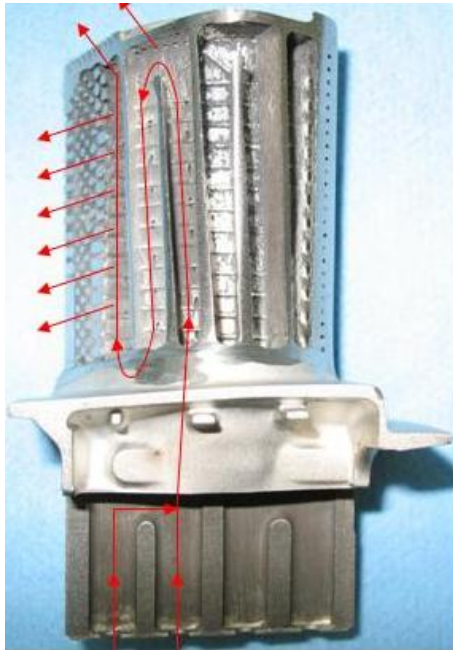


Life Analysis

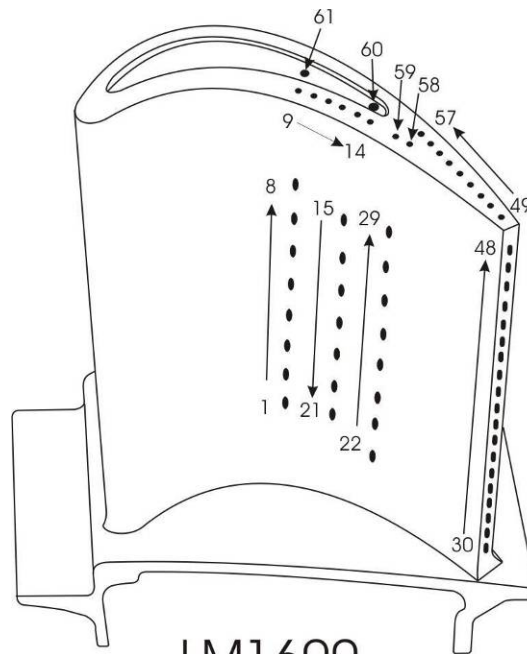


Incoming Inspection

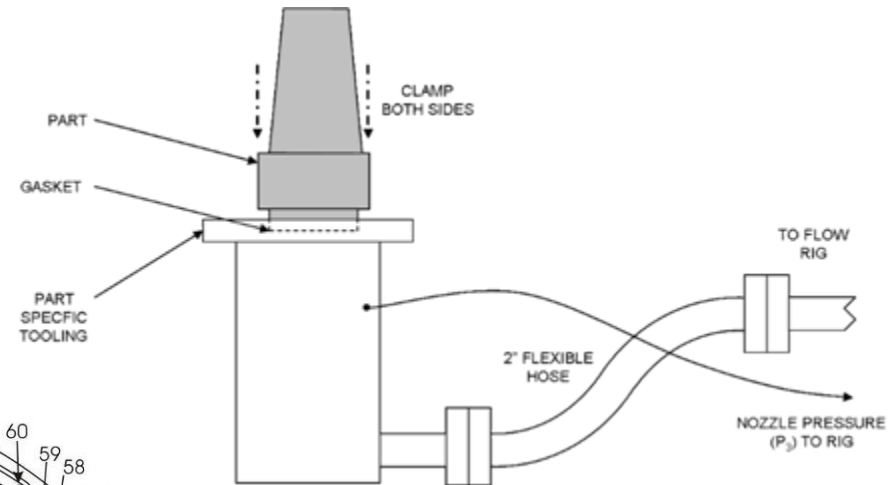
- Cooling Hole Inspection
- Air Flow
- Cooling Flow Analysis



Trailing-Edge Circuit

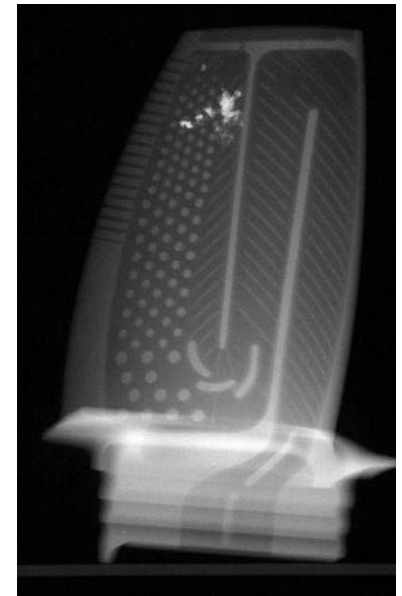
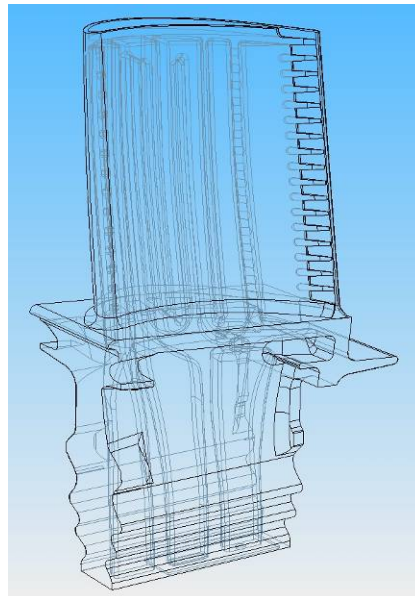
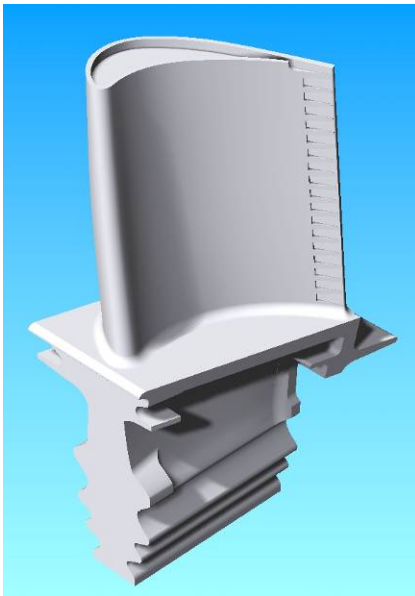


LM1600



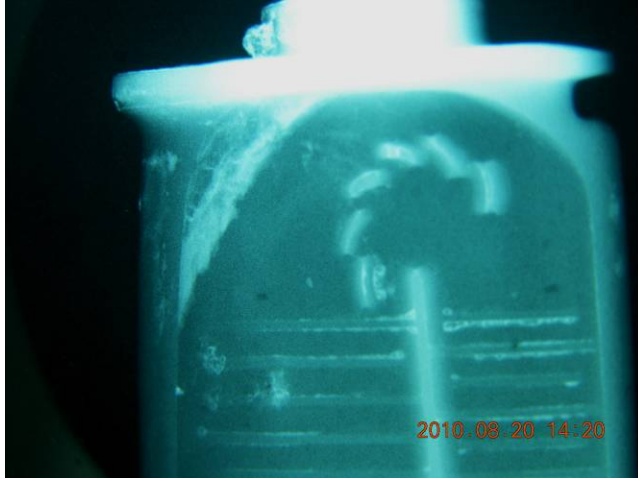
Incoming Inspection

- Internal Geometry



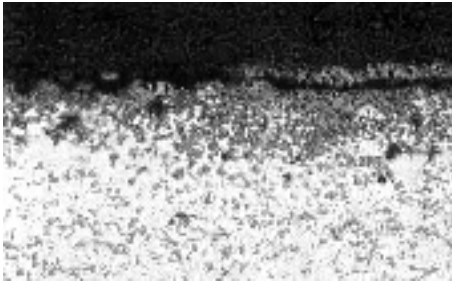
Internal Cleaning

- Internal Cleaning using thermal and chemical process are necessary before stripping
 - Internal deposits and oxides limit effectiveness of stripping process

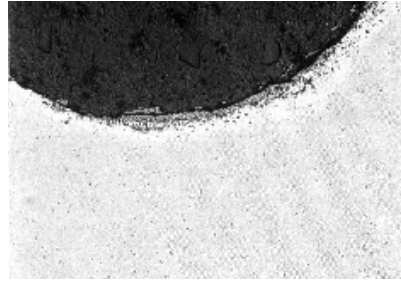


Internal Cleaning

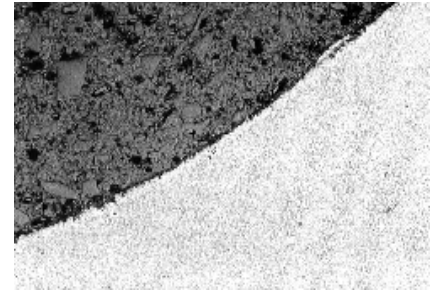
- Oxide removal allows complete stripping



Before cleaning

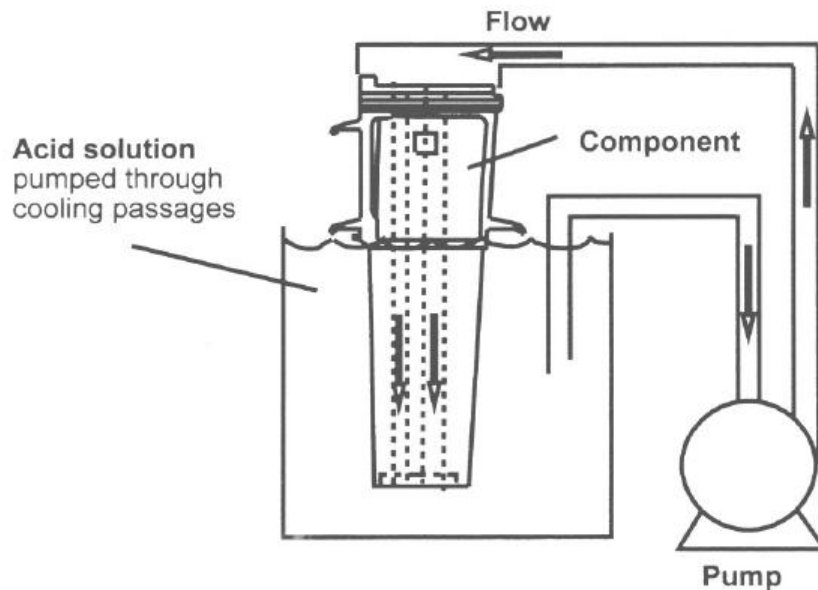


After cleaning



Coating Stripping

- Masking Required for Internal Only Strip
- Internal Stripping

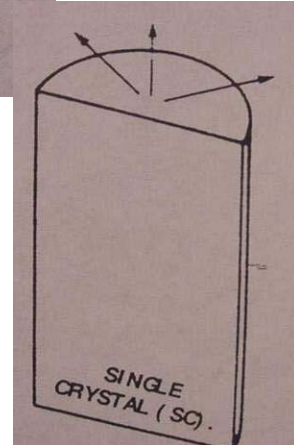
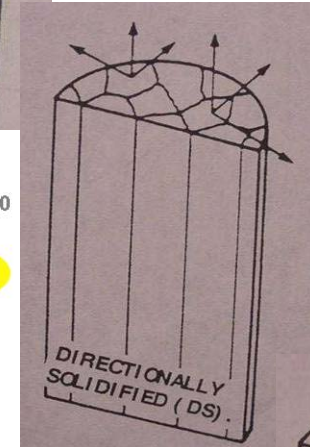
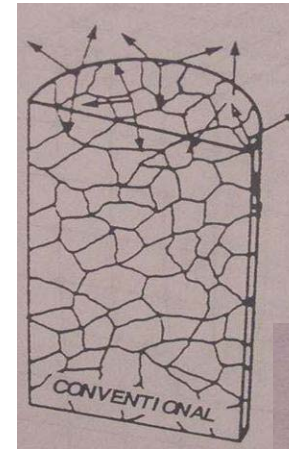
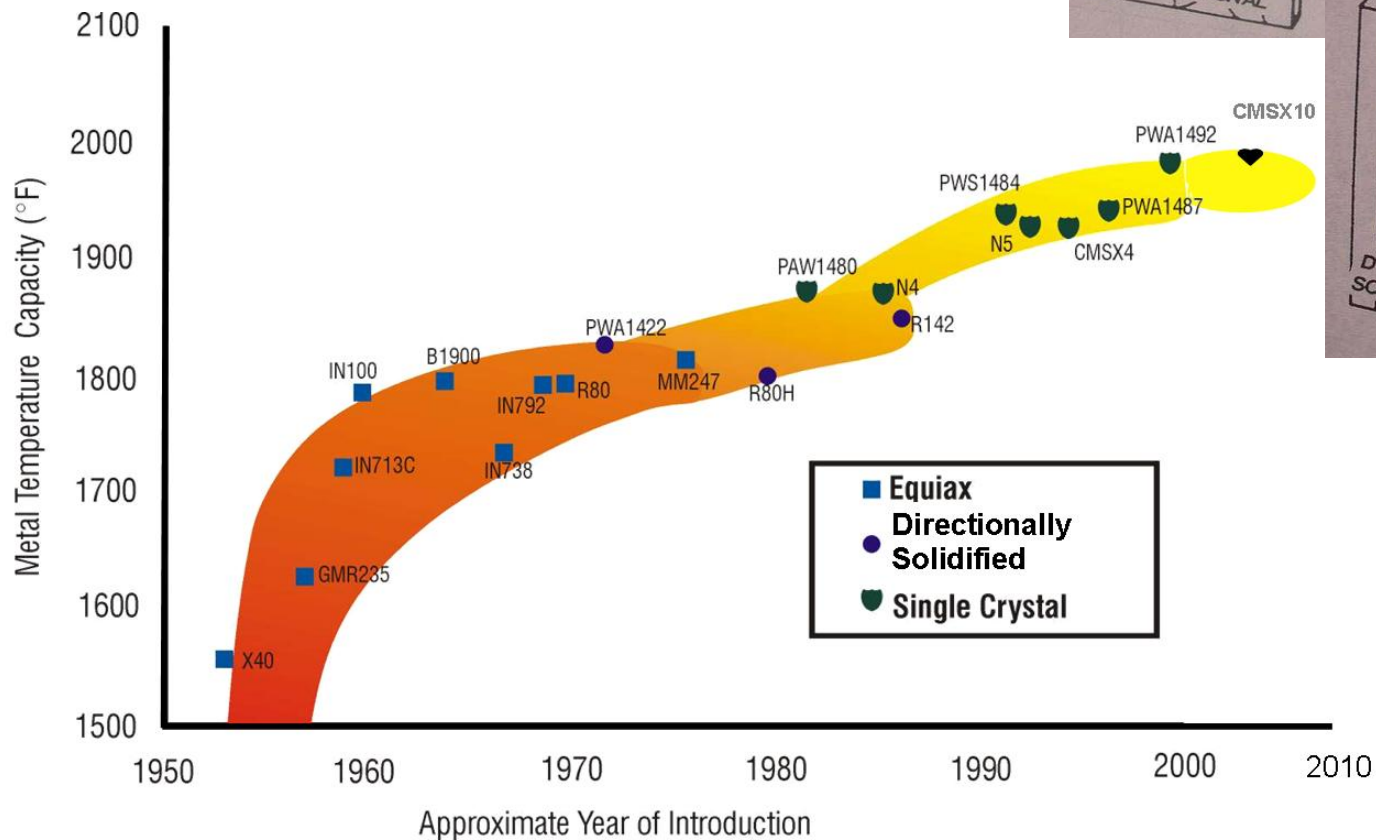


Dimensional Repair

- Tip weld of un-shrouded blades
- Z-notch restoration of shrouded blades
- Seal fin restoration

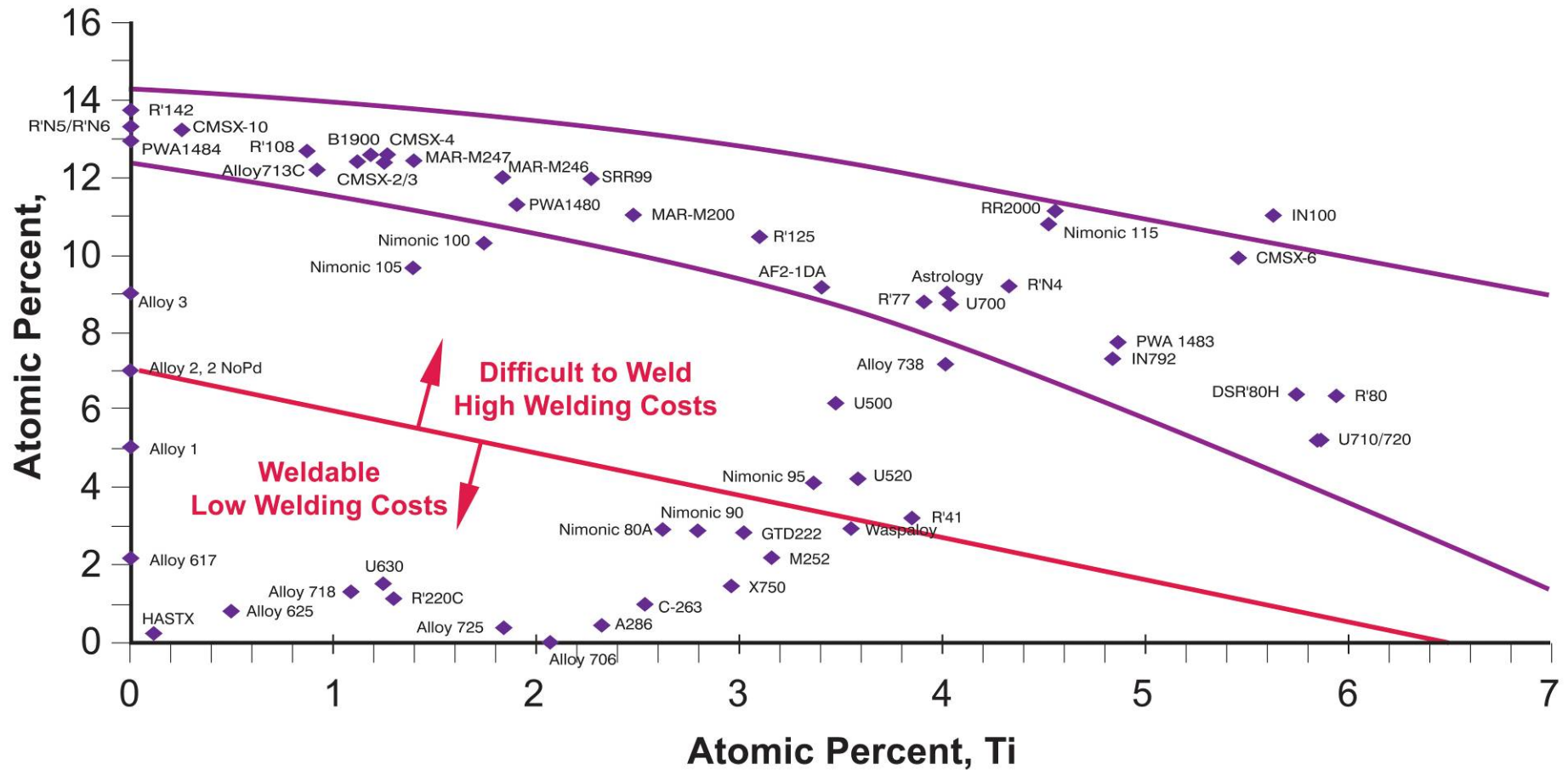


Materials



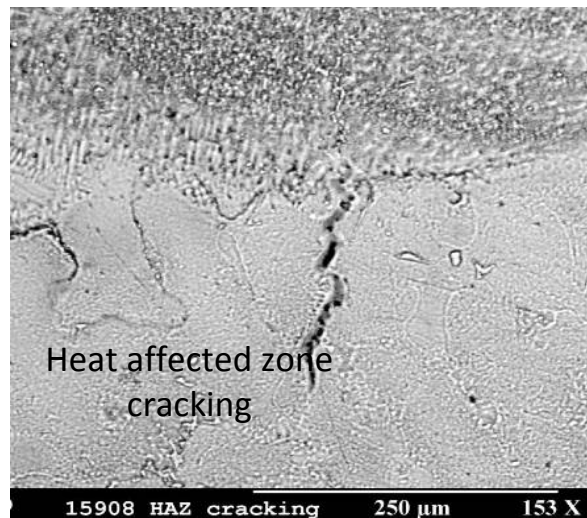
Weldability

Weldability of Superalloys



Dimensional Repair

- Welding of gamma prime (γ') strengthened superalloys is not as easy when compared to welding of cobalt base alloys or stainless steel alloys.
- Fusion Zone cracking
- HAZ cracking (microfissuring)
- Post weld heat treat cracking (strain age cracking)



Material Selection



New Blade



Repaired Blades



Geometry Repair - Vanes

Liburdi Powder Metallurgy (LPM™) is a modified wide gap brazing process.

Can be used to fill very large gaps of more than 0.5" size

Build-up damaged surfaces

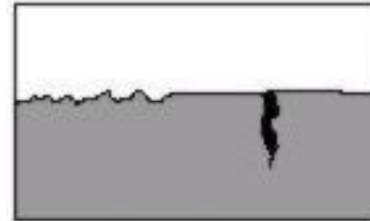
Up to 0.15" thick per application, multiple layers per repair

Heat treatments tailored to match the substrate alloy.

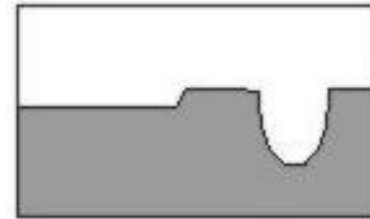
Component distortion greatly reduced using LPM™ compared to conventional weld methodology.

Much stronger than braze repairs.

Nickel based LPM™ materials can be applied to nickel, cobalt and stainless steel alloys.



Crack, crazed & oxidized surface



Blend to remove crack, crazing & oxidation



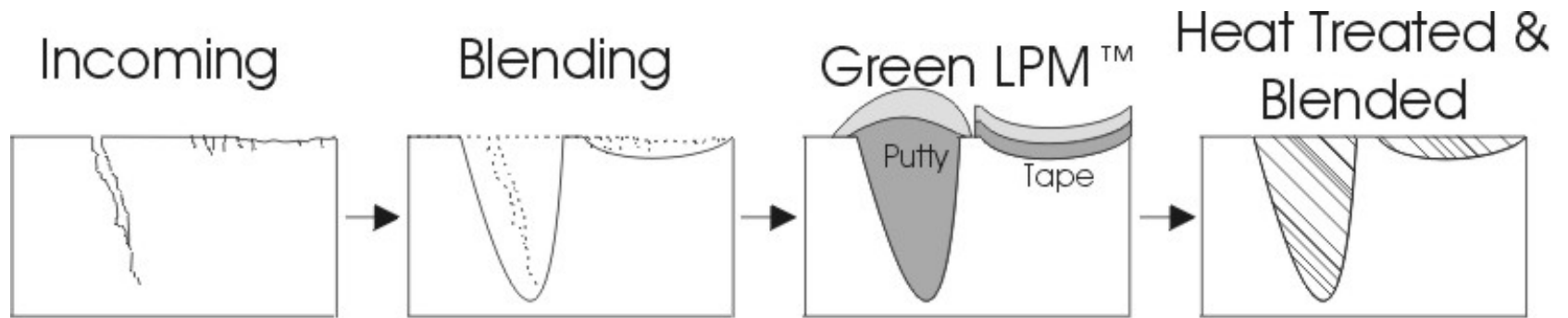
LPM™ applied to surfaces



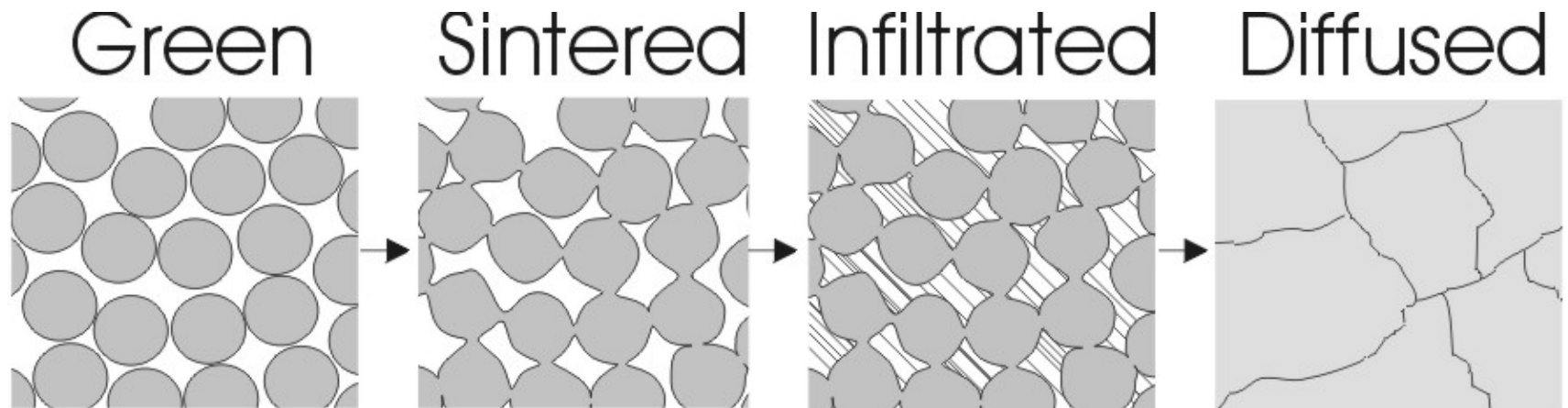
Heat treated and blended deposits



Geometry Repair - Vanes



□ Low Melt ■ High Melt ▨ Consolidated



Geometry Repair - Vanes

Original braze joint
requires
repair/restoration



- Incoming damage – burned leading and trailing edges, thin airfoils, burned outer shroud surfaces, shroud braze joints deteriorated

- Previously NGVs were considered not repairable and were replaced with new.

Severely burned
trailing edges

Geometry Repair - Vanes



- LPM high strength alloy as-applied to leading edge, mid airfoil, and trailing edges

- LPM material after high temperature vacuum heat treatment to "cast" material to the airfoils



Geometry Repair - Vanes



- Airfoils machined to original contours, all cooling holes re-established by EDM machining, airfoils re-coated, and shrouds coated with TBC coatings. **NVGs fully restored for continued service**

Geometry Repair - Vanes

Significant missing material
on leading edge due to FOD

To maintain cooling design
internal geometry must be
recreated during repair

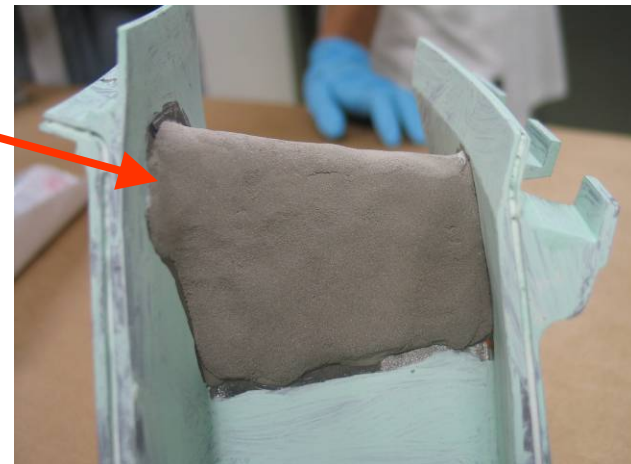
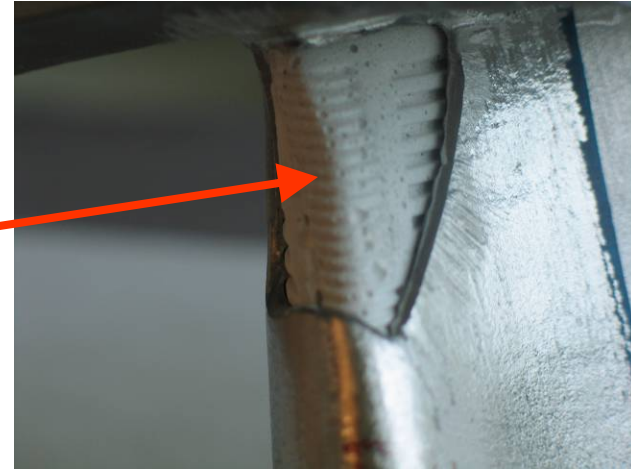


Geometry Repair - Vanes

Form casting process allows
LPM to be formed to match
internal geometry

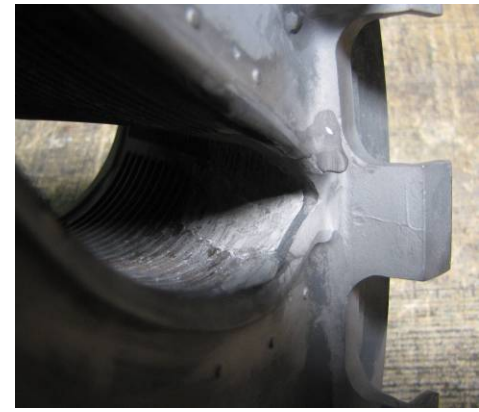
Reduces post consolidation
machining operations

LPM™ superalloy applied
over form and onto base
alloy

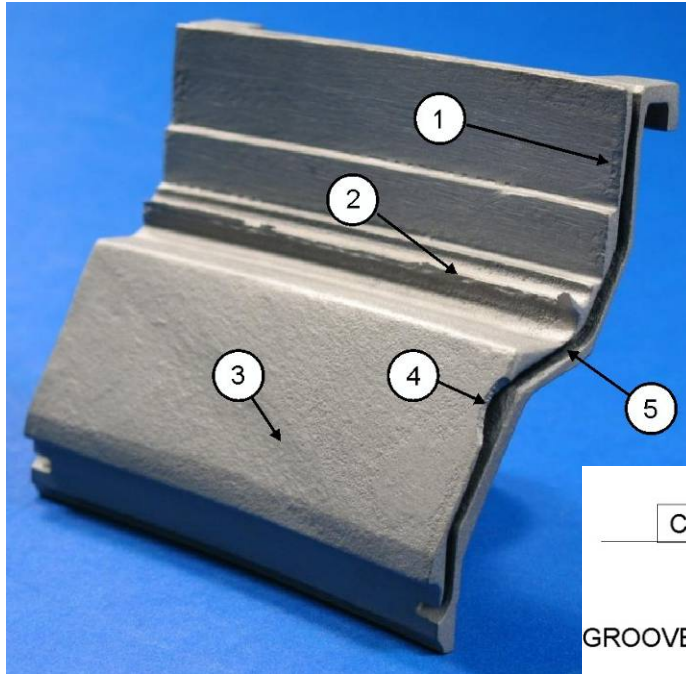


Geometry Repair - Vanes

Part returned for repair after 24,000 hours
Inspection revealed no indications or material loss

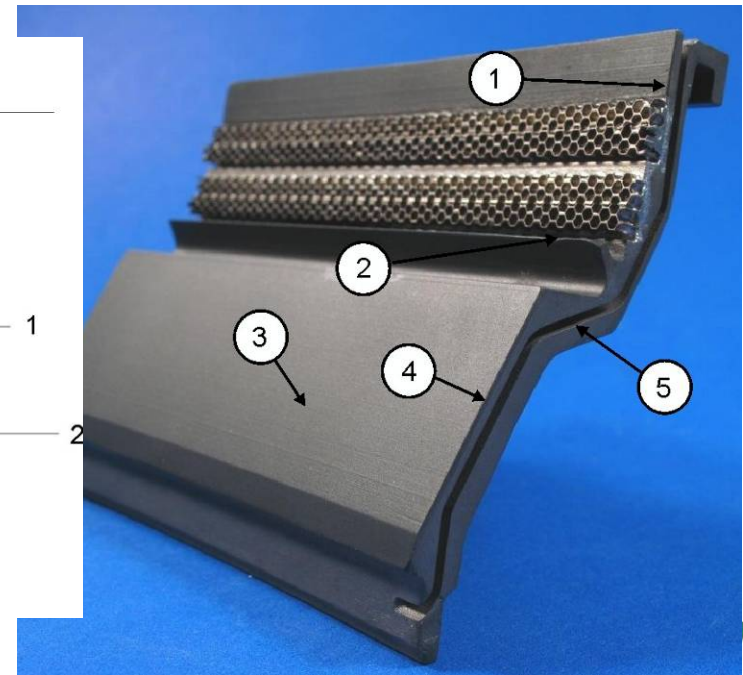
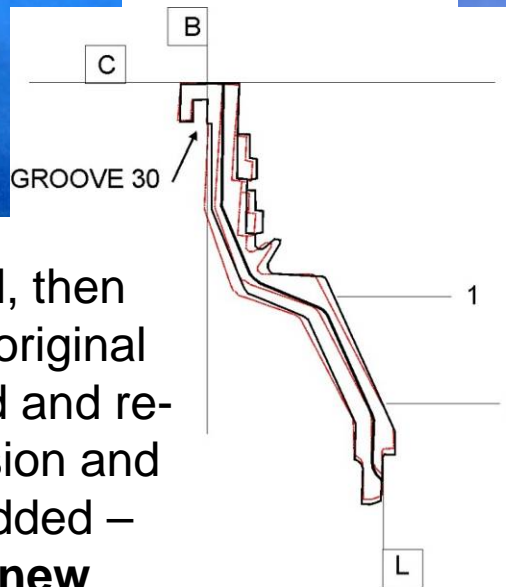


Geometry Repair - Vanes

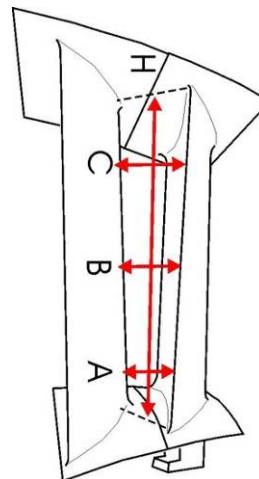
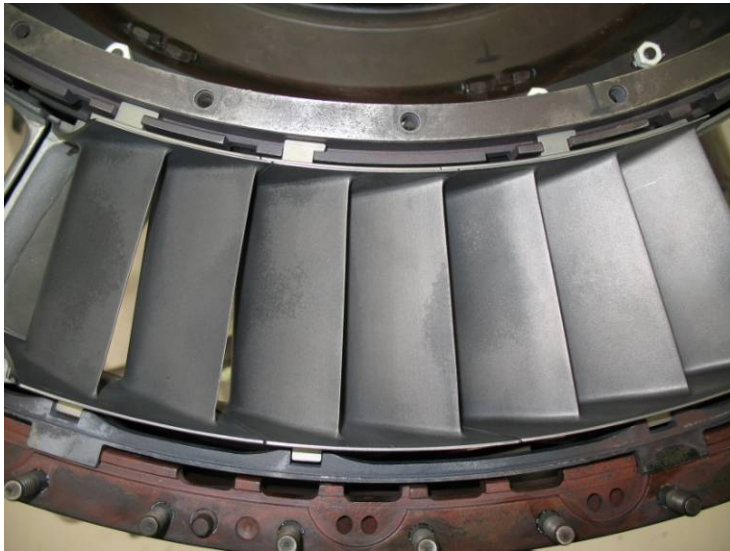
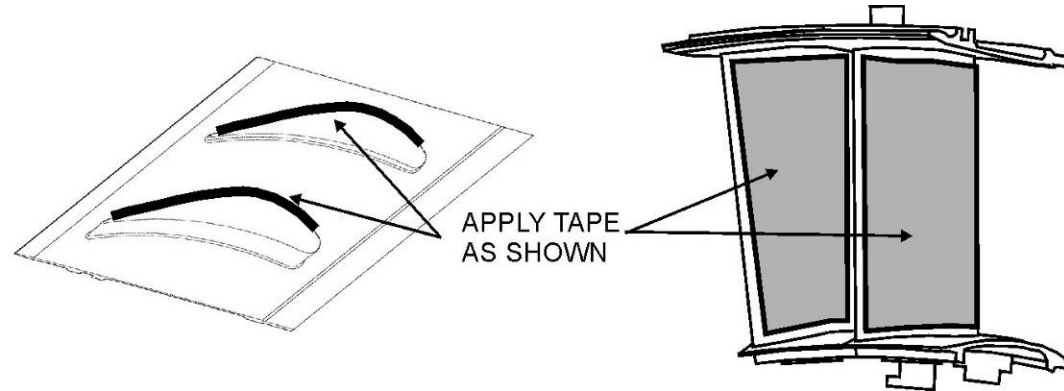


- Incoming seal segs distorted (out of round), seal slots misaligned, backing plates thin due to oxidation – parts were previously declared scrap and replaced with new

- Backing plate is re-formed, then thickened and machined to original dimensions. Seal slots filled and re-machined to original dimension and location, new honeycomb added – **parts reconstructed to as-new dimensions for continued service**



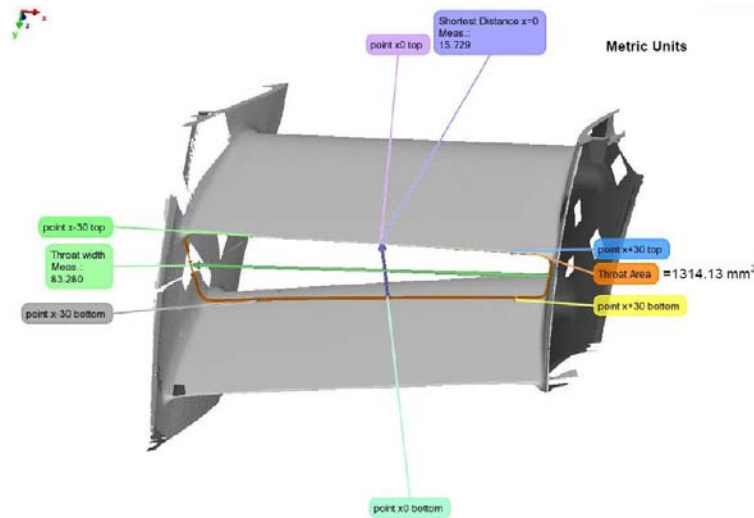
Geometry Repair - Vanes



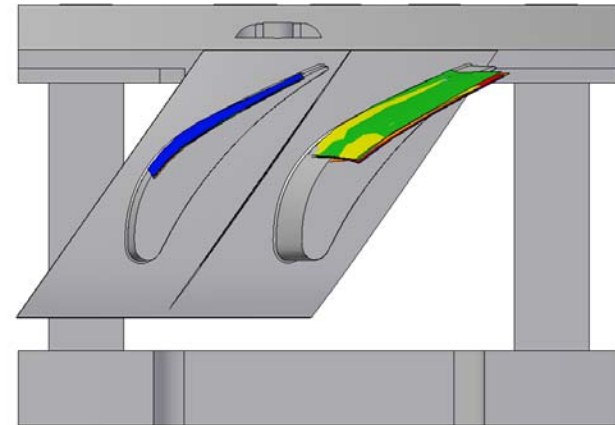
- LPM superalloy sheets of required thickness are applied to the airfoils
- Parts are heat treated in vacuum furnace to bond and diffuse the LPM into the airfoil castings
- The airfoils are final machined to original throat dimensions
- **Final dimensional checks and re-qualify set**

Geometry Repair - Vanes

- White Light Inspection
- CMM Inspection



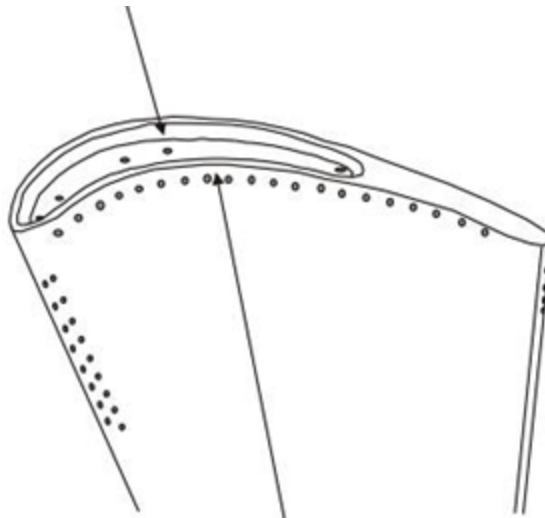
Applied Precision Inc.



Machining / Finishing

- Tip Cap Machining
- EDM Hole Drilling

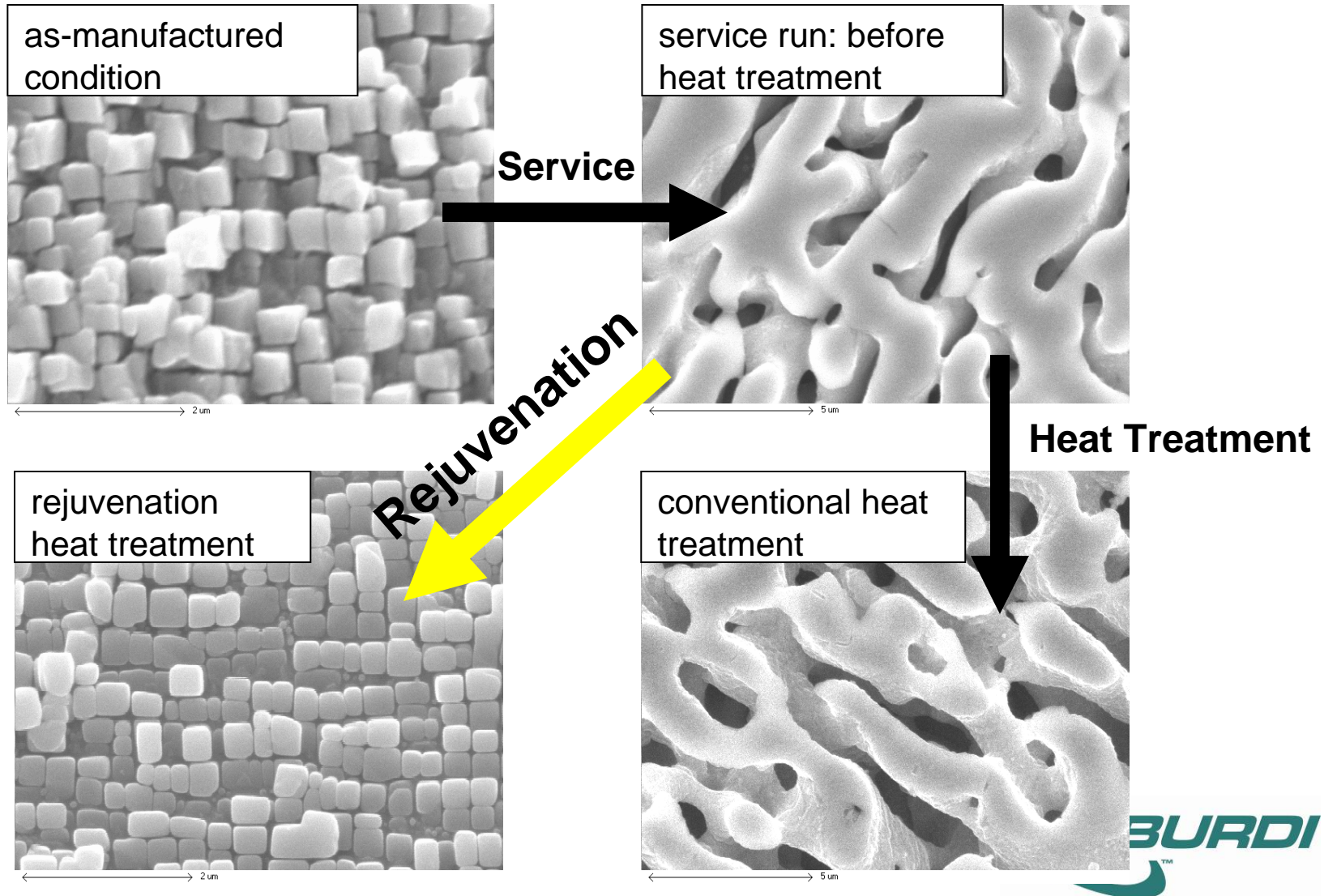
Tip Cap Machining



Cooling Hole Drilling

Heat Treatment

- FSR™ Full Solution Rejuvenation™



Heat Treatment

Effect of Heat Treatment

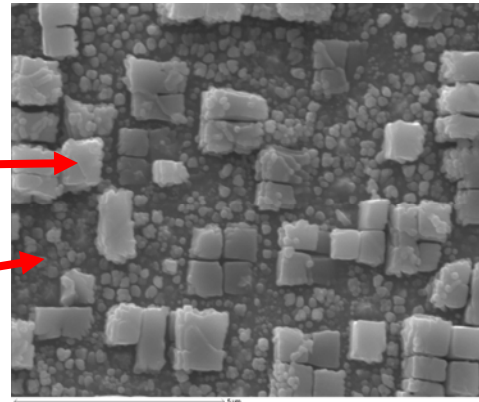
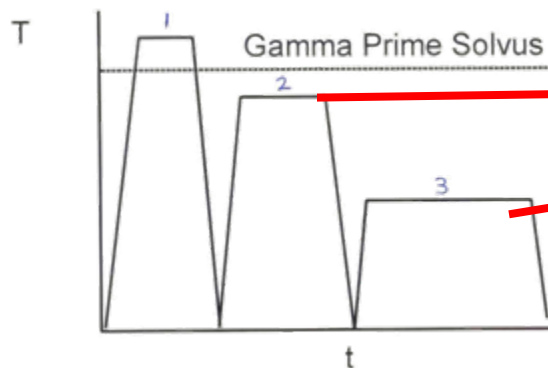
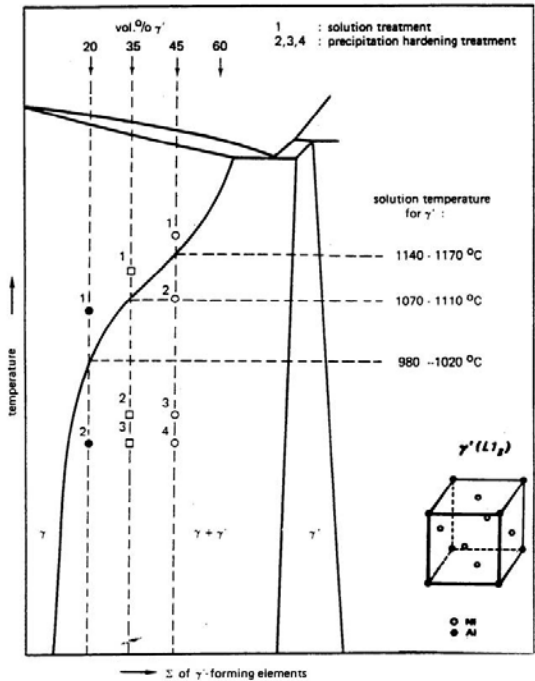
Solutioning

γ' formation

Aging cycles

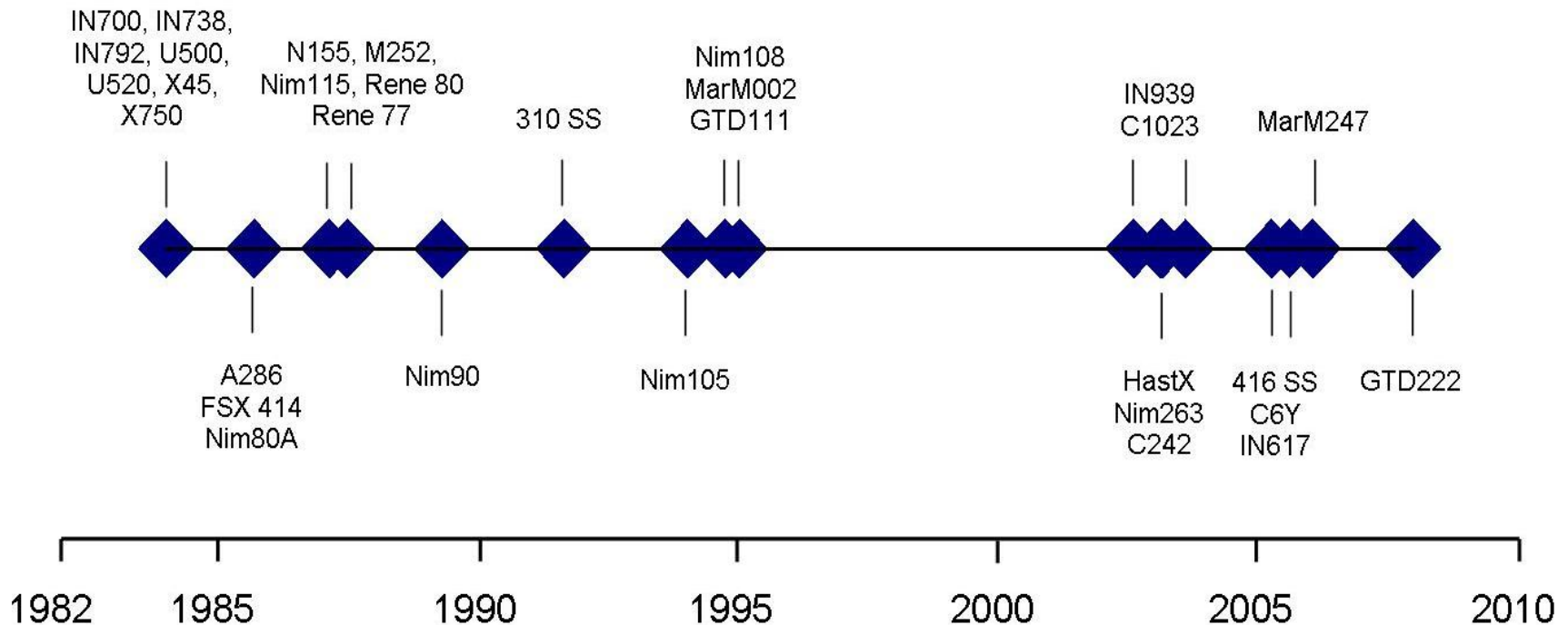
Multiple aging cycles can be used to form a duplex microstructure

Time and temperature parameters are unique to individual alloys



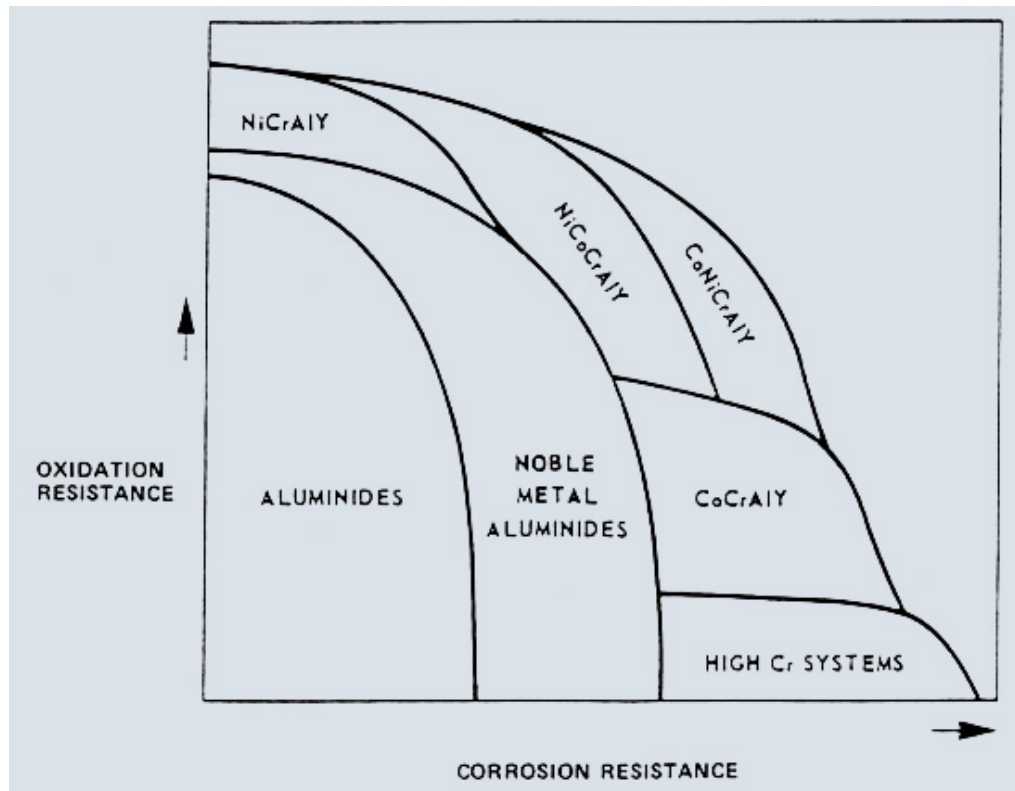
Heat Treatment

Liburdi Turbine Services Heat Treatment Development Timeline



Coating

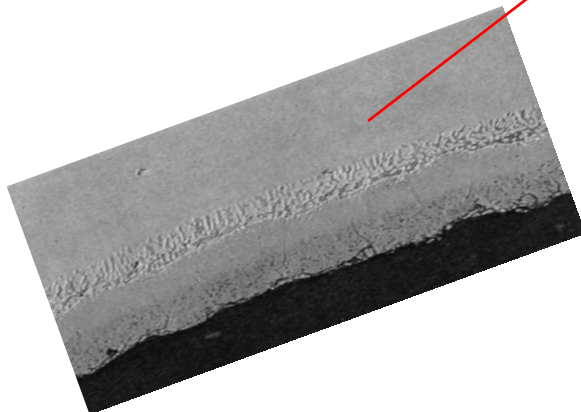
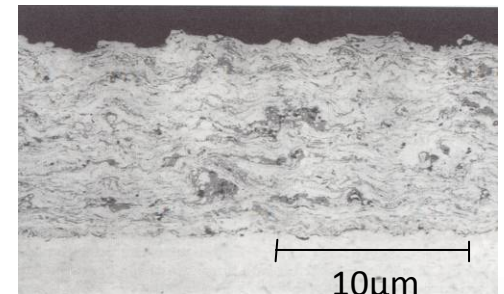
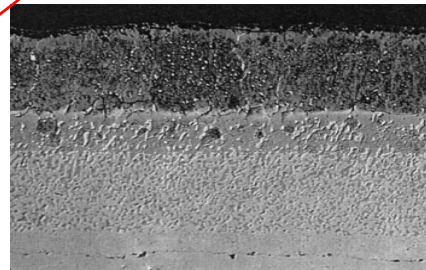
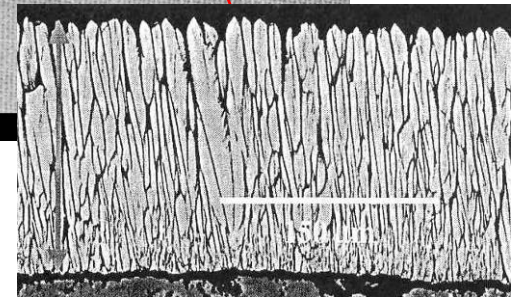
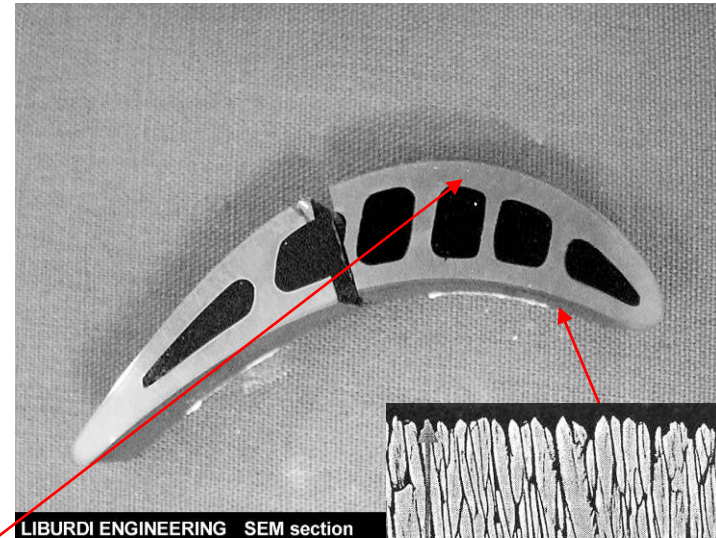
- Selection of Coating System



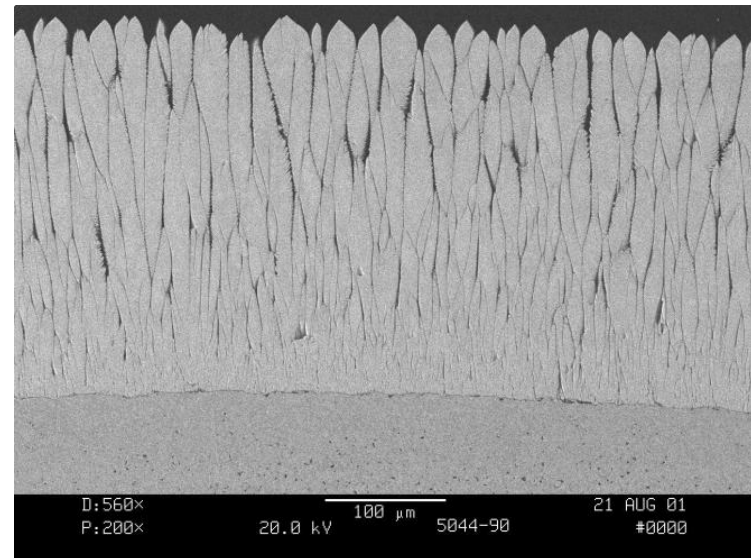
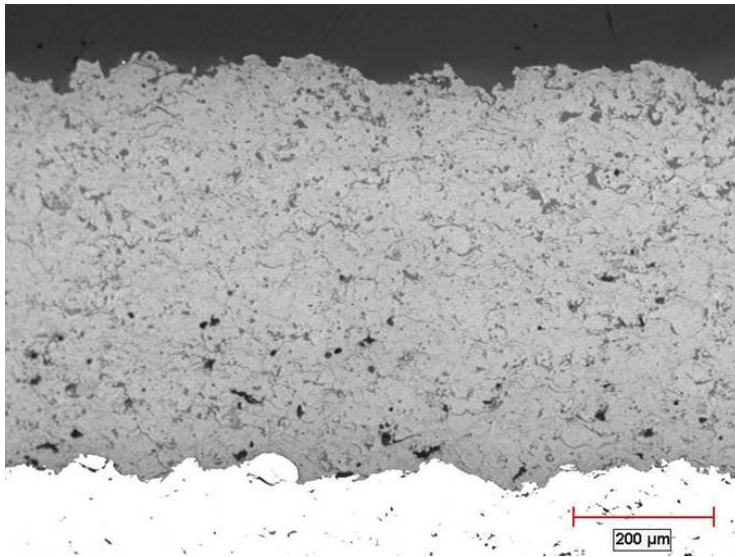
Coating

External airfoil surfaces – MCrAlY with over aluminize or MCrAlY bond coat with DVC or EB-PVD TBC.

Recoating internal airfoil surfaces – diffusion aluminide or silicon aluminide



Coating



Thanks for Listening.



Any Questions?

