IAGT
Industrial Application of Gas Turbines

IAGT 2015 SYMPOSIUM

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Training Session 5: Gas Turbine Repair

By
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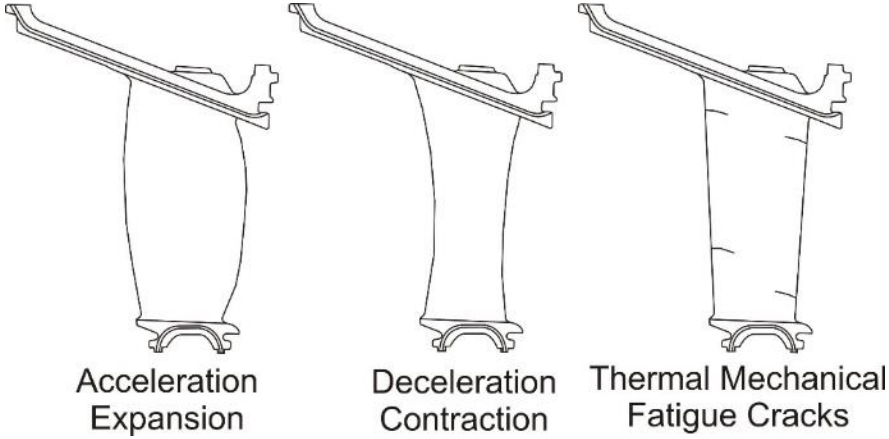
Why do we need to Repair?

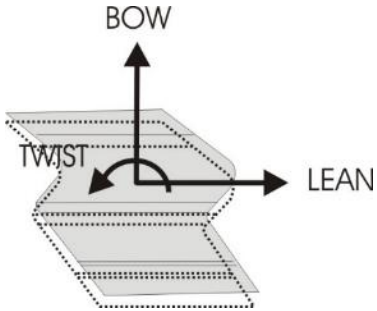
- Maintenance after fuel is the main operating cost over the life cycle of a GT
- Spare part replacement and repairs of hot section components represent the major cost portion of all maintenance
- Typically component repairs cost 10% to 30% of the replacement new part cost
- Repairs represent main cost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

When do we need to Repair?

- Meet OEM recommended schedules
- Based on condition – vibration or borescope inspection
- Before a part fails
- Before the part is damaged beyond repair
- When an engine performance limit is reached
- At the same time as other parts to match maintenance cycles

What do we need to Repair?





What do we need to Repair?

What are the Materials?

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

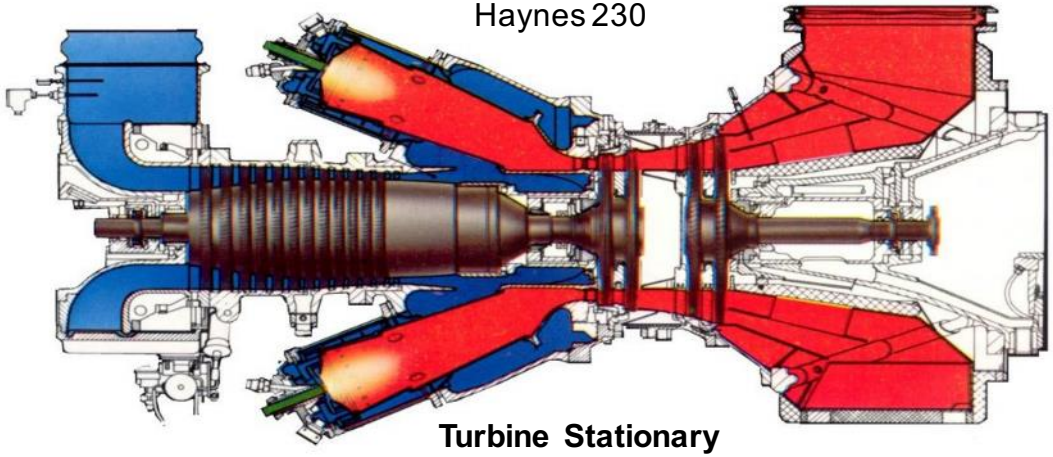
Combustor
300SS
Hastelloy-X, RA-33
IN-600, IN-617
Nimonic 75, Nimonic 263
Haynes 230

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

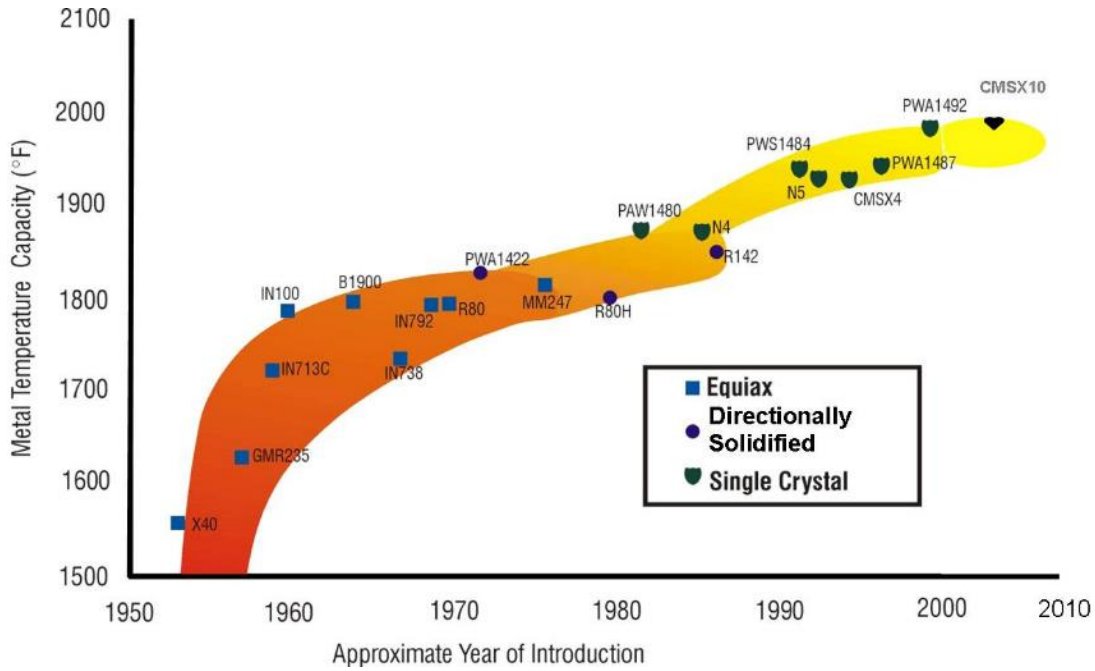
Turbine Wheels/Discs
Ni-Cr-MO-V Steel
Cr-Mo-V Forging
12Cr Stainless
Discalloy
A286
IN718

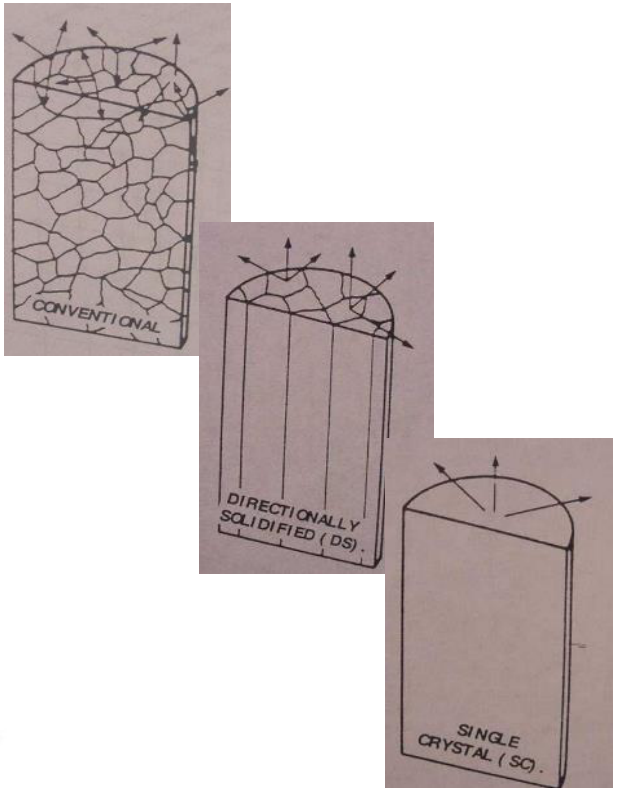


Turbine Rotating
N105, N108, N115, Waspalloy, U-500, U520,
U700, U710, U720, INX750, IN738,
Rene80, GTD111, Mar-M247, Mar-M002,
PWA1483, CMSX4, ReneN5

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

What are the Materials?





Where do we Repair?

Industrial Frame Gas Turbine

↓

Disassembled in Field

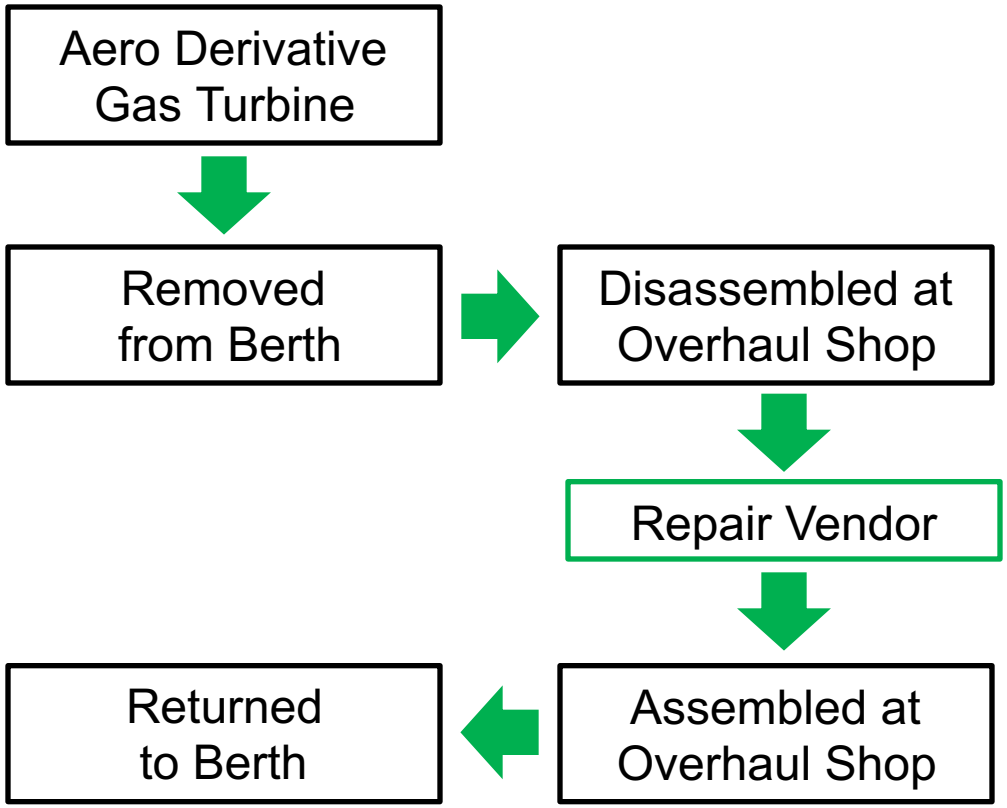
↓

Repair Vendor

↓

Assembled in Field

Where do we Repair?



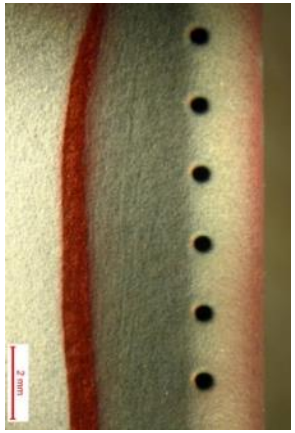
How do we Repair?

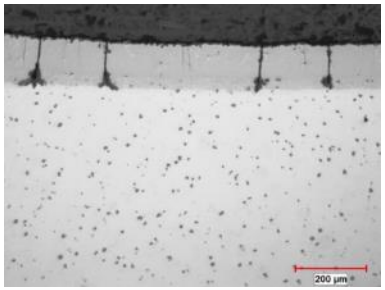
Repair Process

- Incoming Inspection
- Clean & Strip Coatings
- Post Coating Inspection
- Geometry Repair
- Machine/Finish Geometry
- Heat Treatment
- Pre-Coating Inspection
- Coating
- Final Inspection

Incoming Inspection

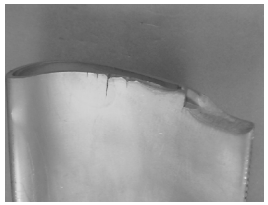
- Triage
  - Is the component repairable?
  - What is the expected level of the repair
- For higher technology components Metallurgical Life Analysis is required

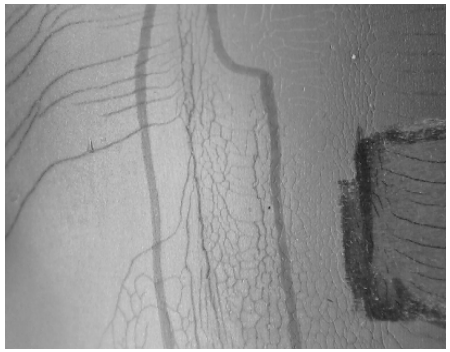


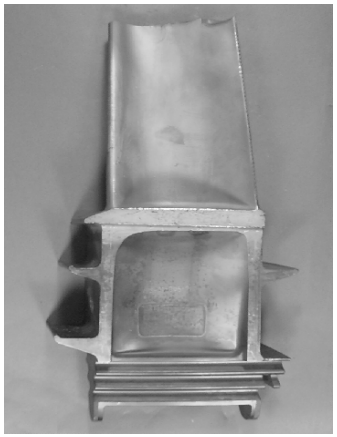


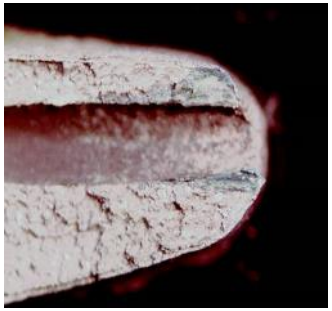
Life Analysis

- Looking beyond what external inspections can see
- Causes of material loss
- Internal cracking
- Internal coating quality

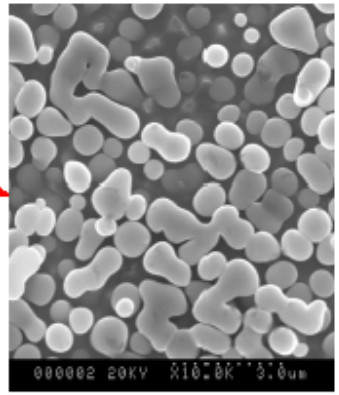


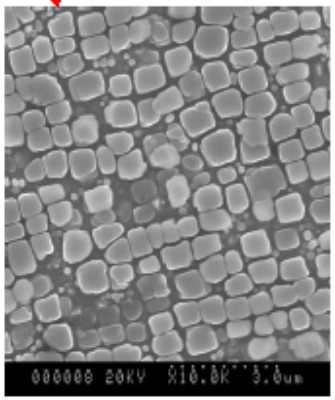


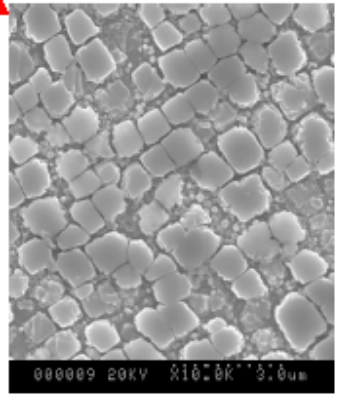




Life Analysis

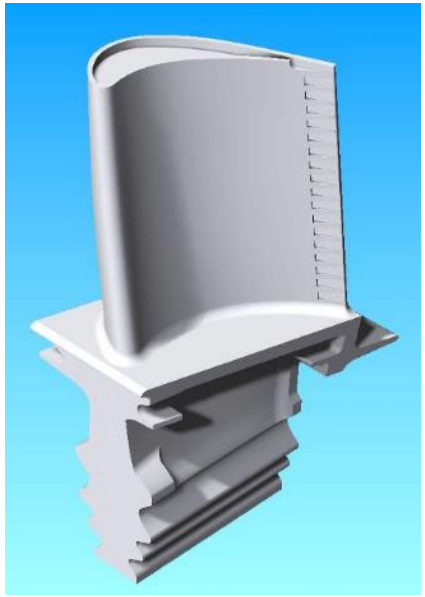
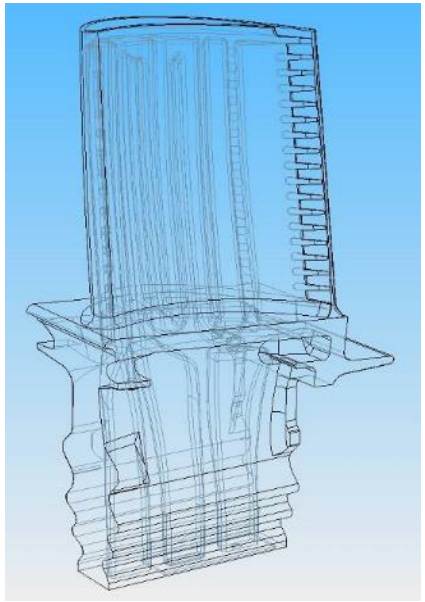


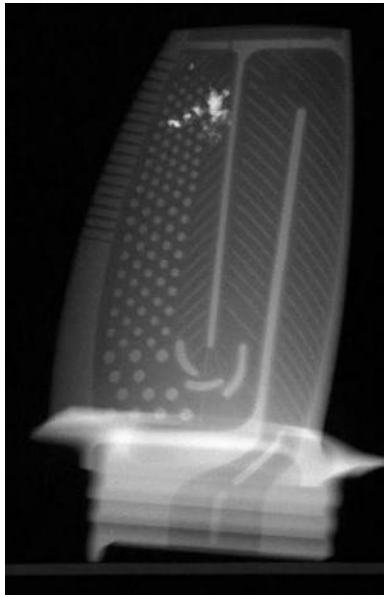




Incoming Inspection

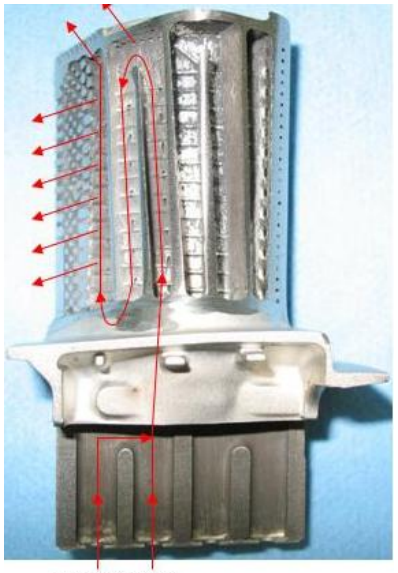
- Internal Geometry

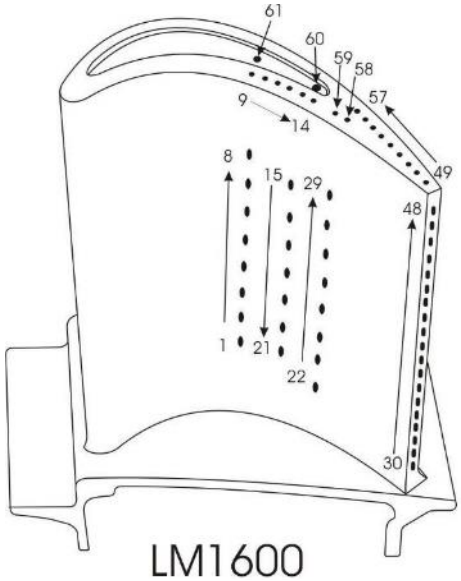





Incoming Inspection

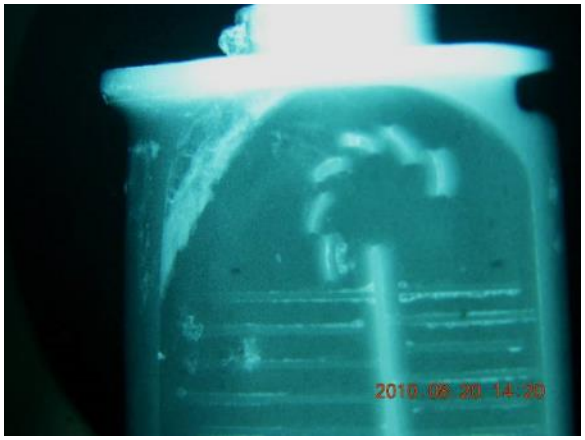
- Cooling System Inspection
  - Qualitative and Quantitative





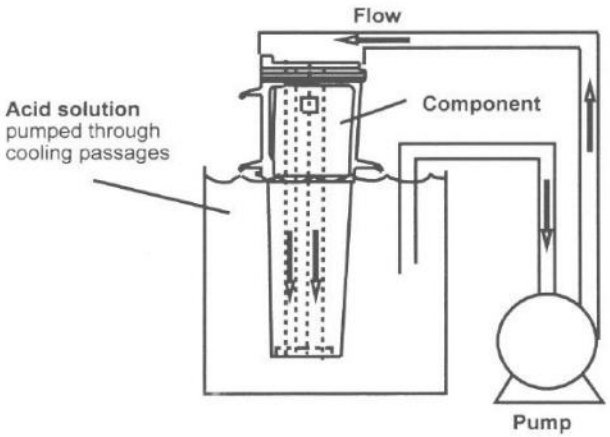
Clean and Strip Coatings

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



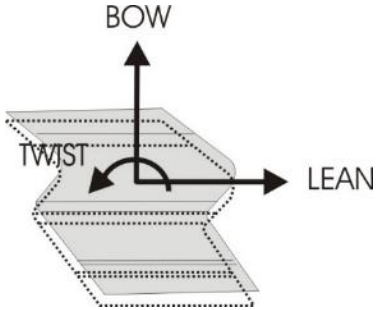
Clean and Strip Coatings

- Acid mix and temperatures based on materials and coatings
- Internal strip requires careful control of acid
- External only stripping possible with masking

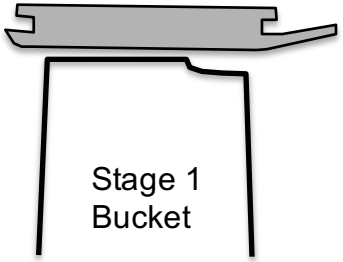


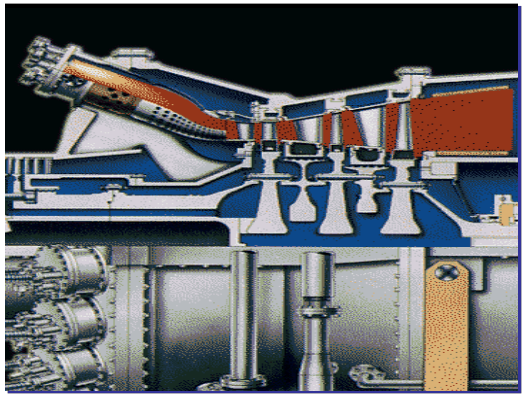
Post Strip Inspection

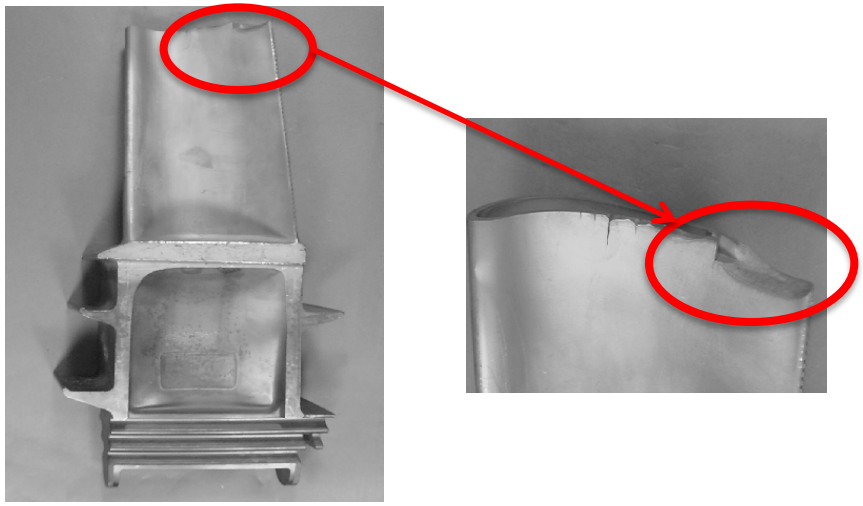
- Fluorescent Penetrant Inspection
  - Find cracks and porosity
- Dimensional Inspection Key Features
  - Blades: Tip height, wall and TE thickness, airfoil geometry, assembly features, deformation
  - Vanes: Wall and TE thickness, deformation, airfoil geometry, assembly features



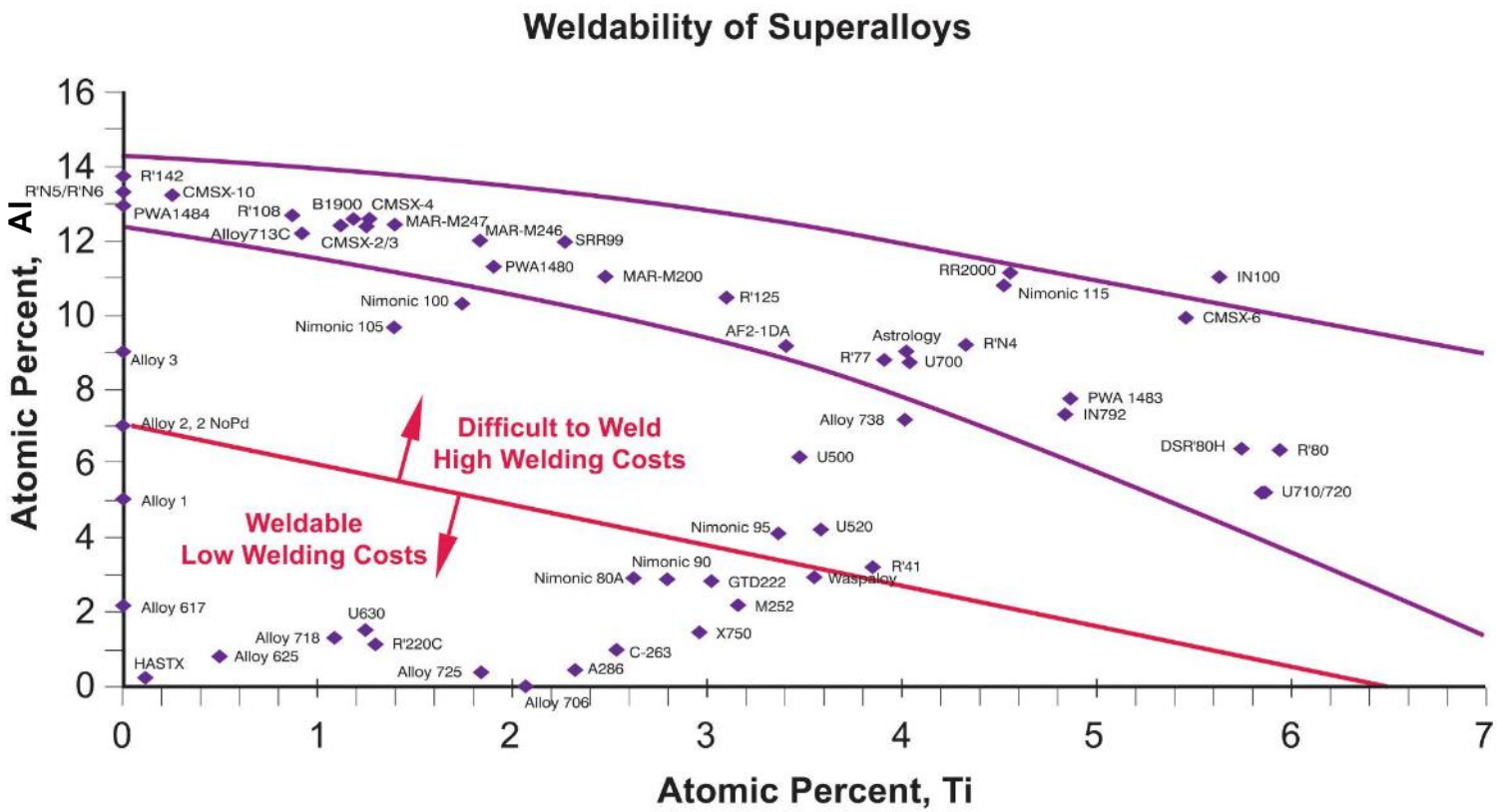
Geometry Repair







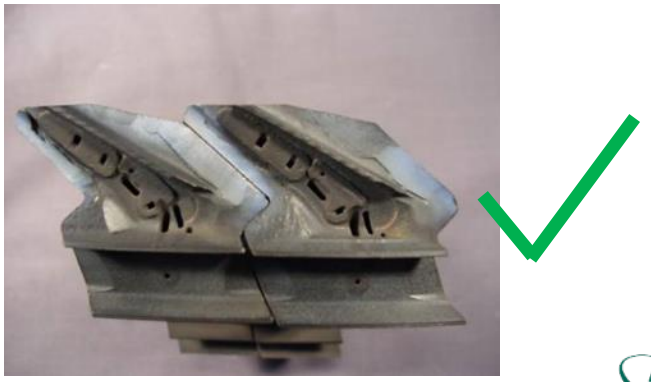
Geometry Repair



Geometry Repair

Blade after First Service

Repaired Blades

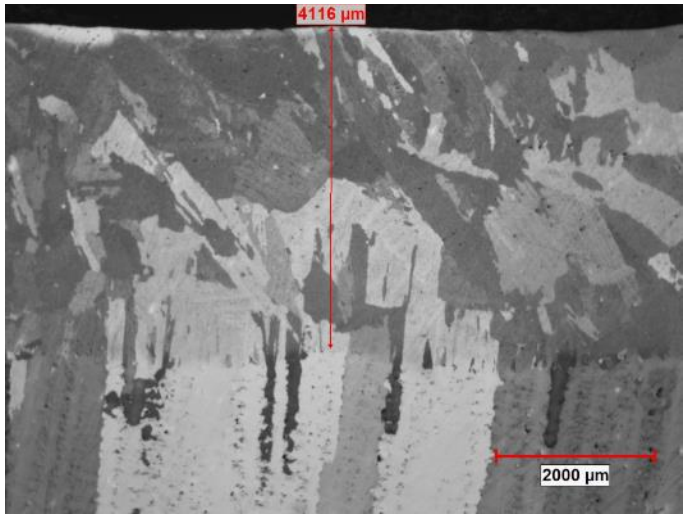


Geometry Repair

- Development of welding alloys with the following attributes:
  - Melting temperature below the incipient melting temperature of base alloys
  - Wide solidification range
  - Sufficient ductility to accommodate welding stresses by plastic deformation within weld beads
  - Strength equal to or greater than conventional repair materials.
  - Cyclic oxidation resistance equal to or greater than that of the base alloy.

Geometry Repair

- Microstructure of the weld
  - Low porosity
  - Excellent fusion
  - No heat affected zone (HAZ) cracking



weld deposit
(silicon modified)

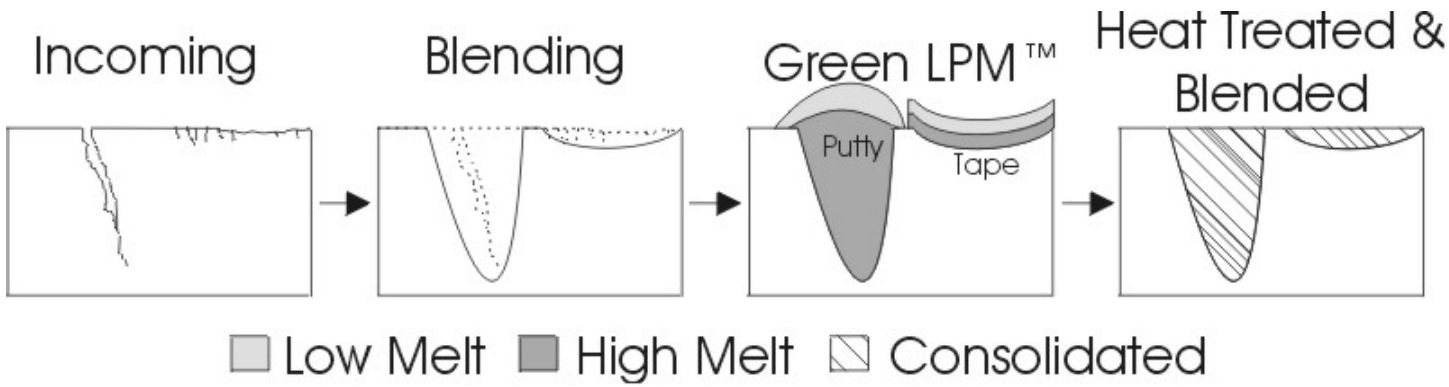
base alloy
(GTD 111)

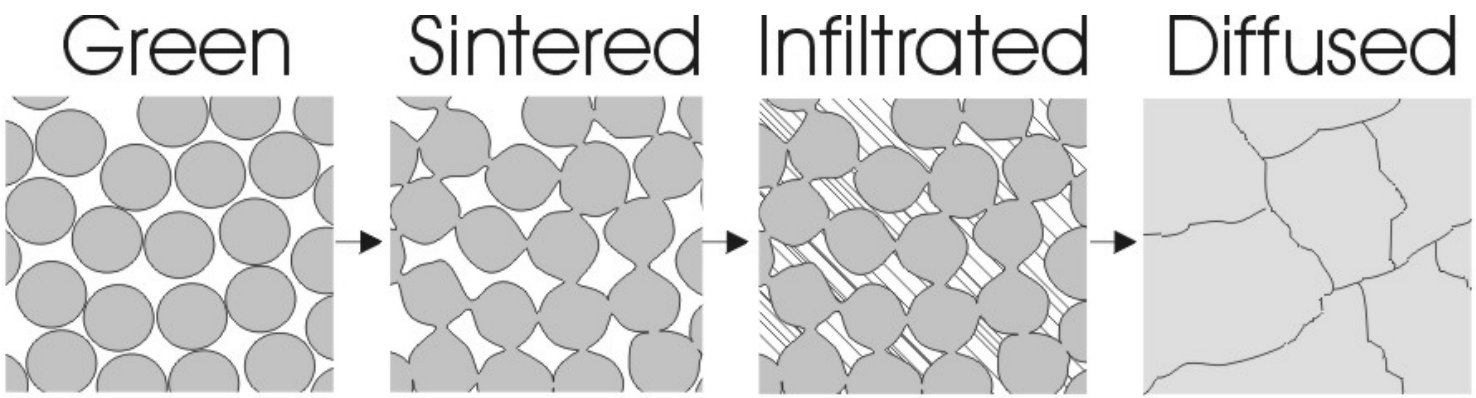
Geometry Repair

- The strength and ductility of the modified weld filler meets or exceeds that of the standard weld filler at low and high temperature

Material	Temperature (°F)	Yield Stress (ksi)	UTS (ksi)	Elongation (%)
Standard Weld	70	120	145	5
	1800	39	47	13
Standard Weld +Silicon	70	137	146	6
	1800	50	55	13

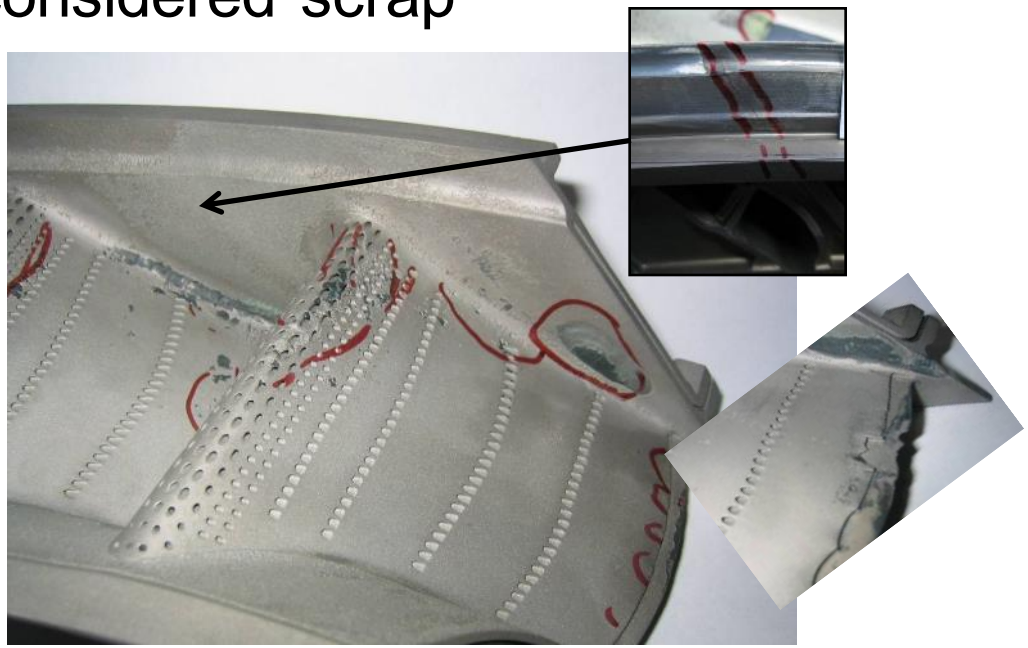
Geometry Repair





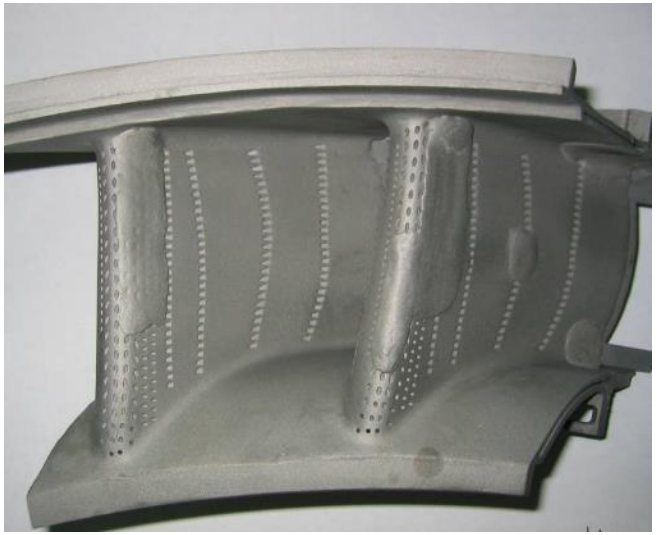
Geometry Repair

- Incoming Damage: Burned LE & TE, deteriorated braze joint, hot corrosion damage
- Previously considered scrap



Geometry Repair

- 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

- 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

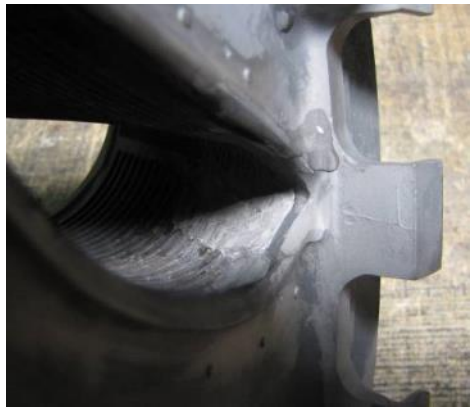
- Significant missing material on leading edge due to FOD
- To maintain cooling design internal geometry must be recreated during repair

Geometry Repair

- Form casting process allows LPM to be formed to match internal geometry
- LPM applied over form and onto base alloy

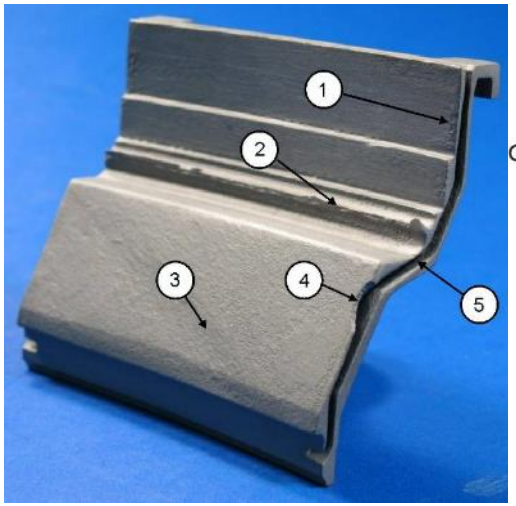
Geometry Repair

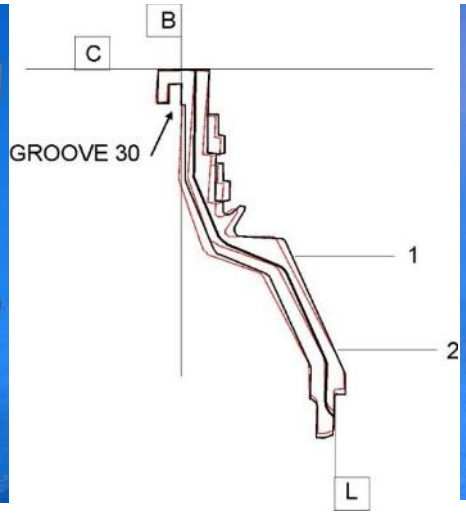
- Part returned for repair after 24,000 hours
- Inspection revealed no indications or material loss

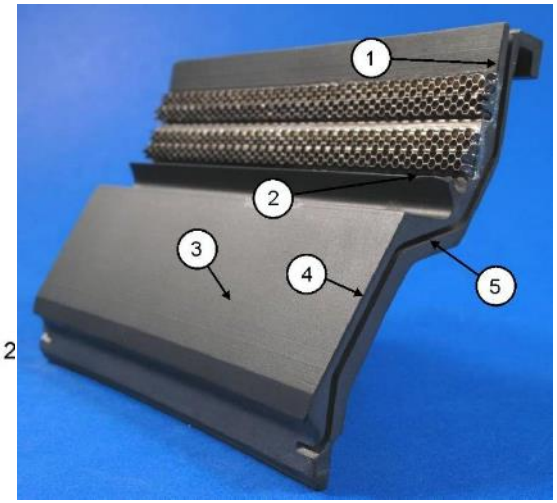


Geometry Repair

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

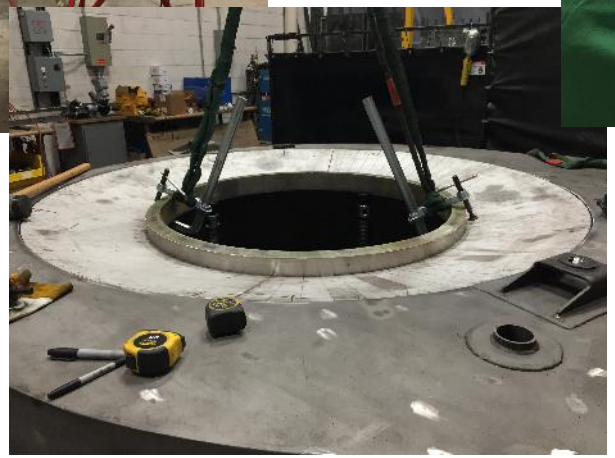






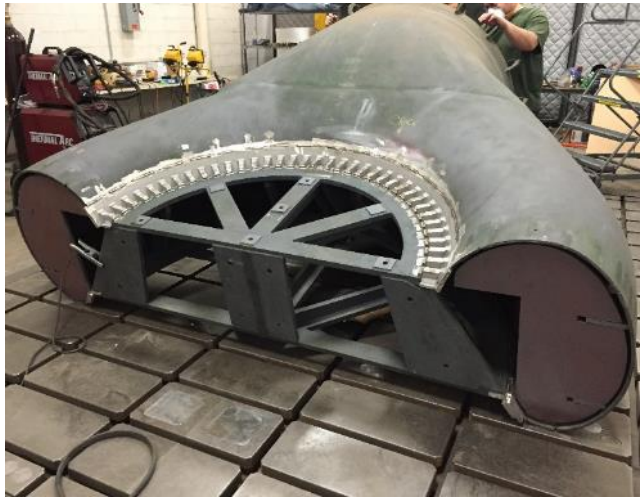
Geometry Repair

- Panel replacement



Geometry Repair

- Reconstruction repair

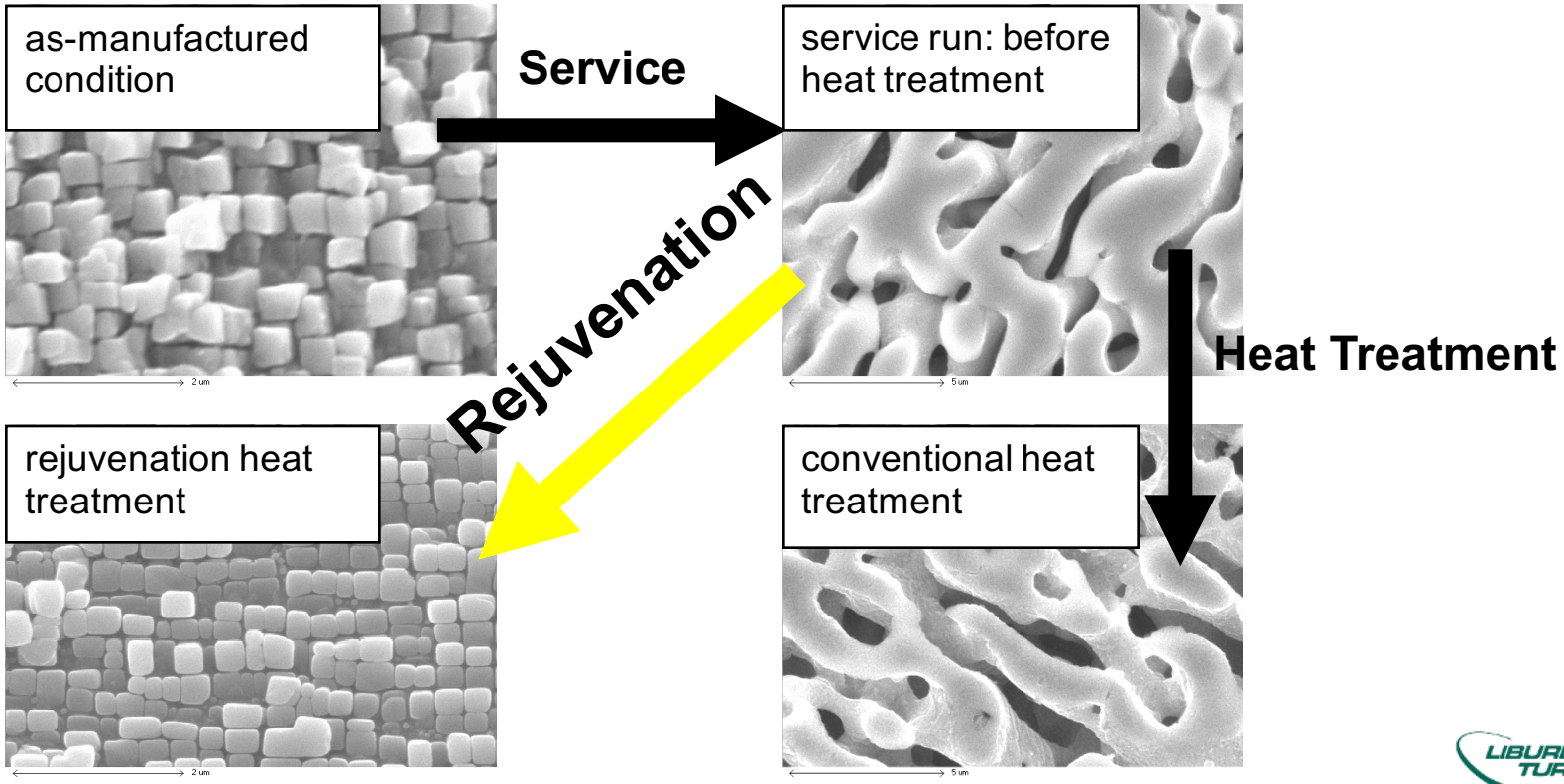


Geometry Repair

- Reconstruction repair

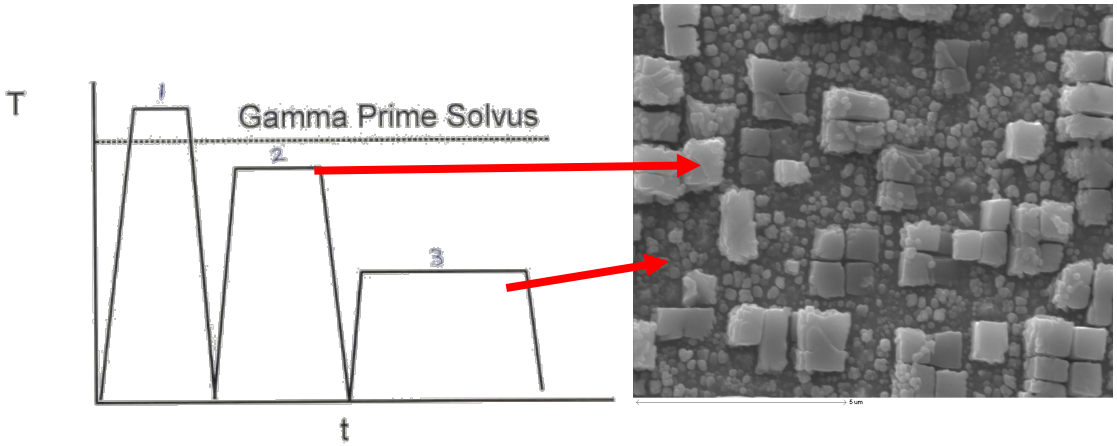
Heat Treatment

- FSR™ Full Solution Rejuvenation™

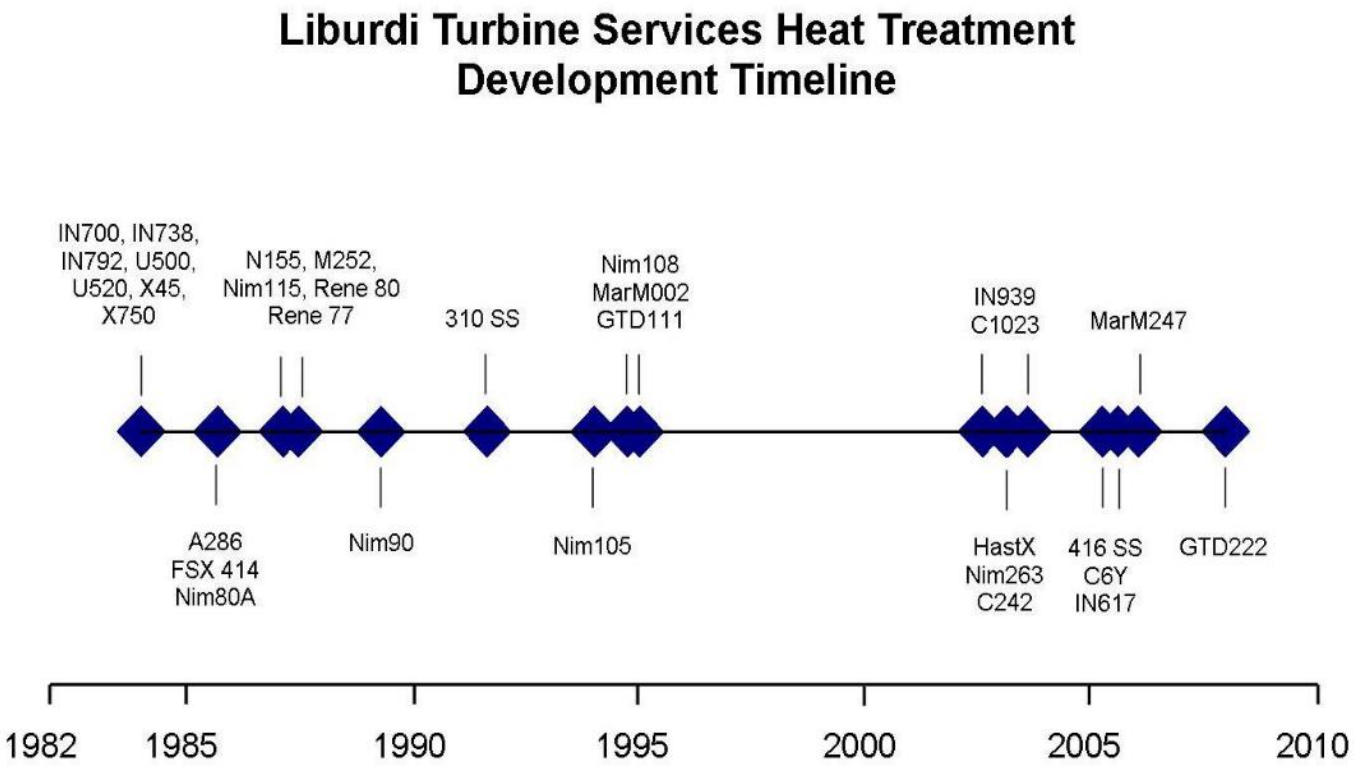


Heat Treatment

- Time and temperature parameters unique to alloys
- Multiple aging cycles used to form a duplex microstructure

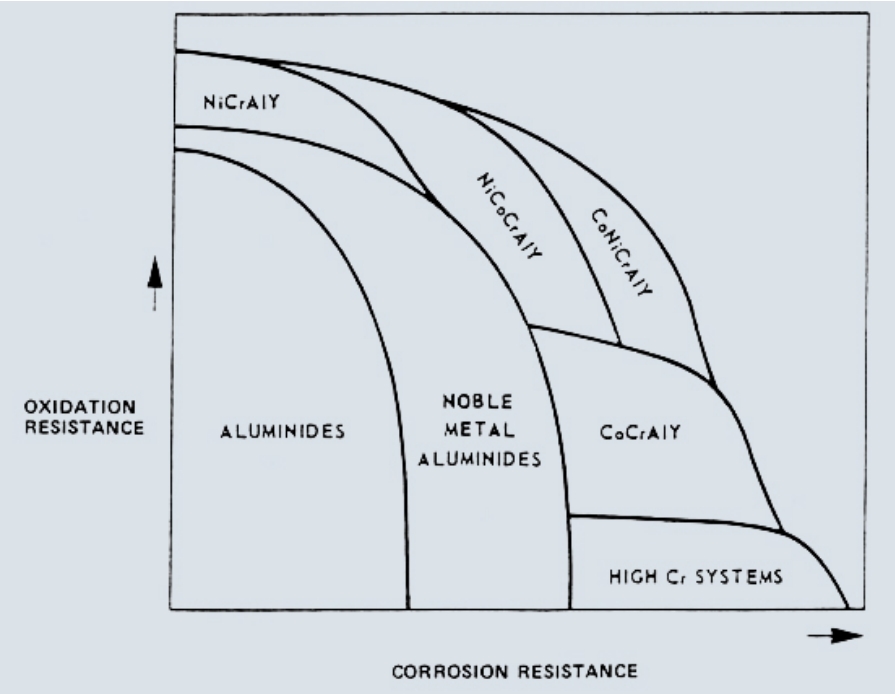


Heat Treatment

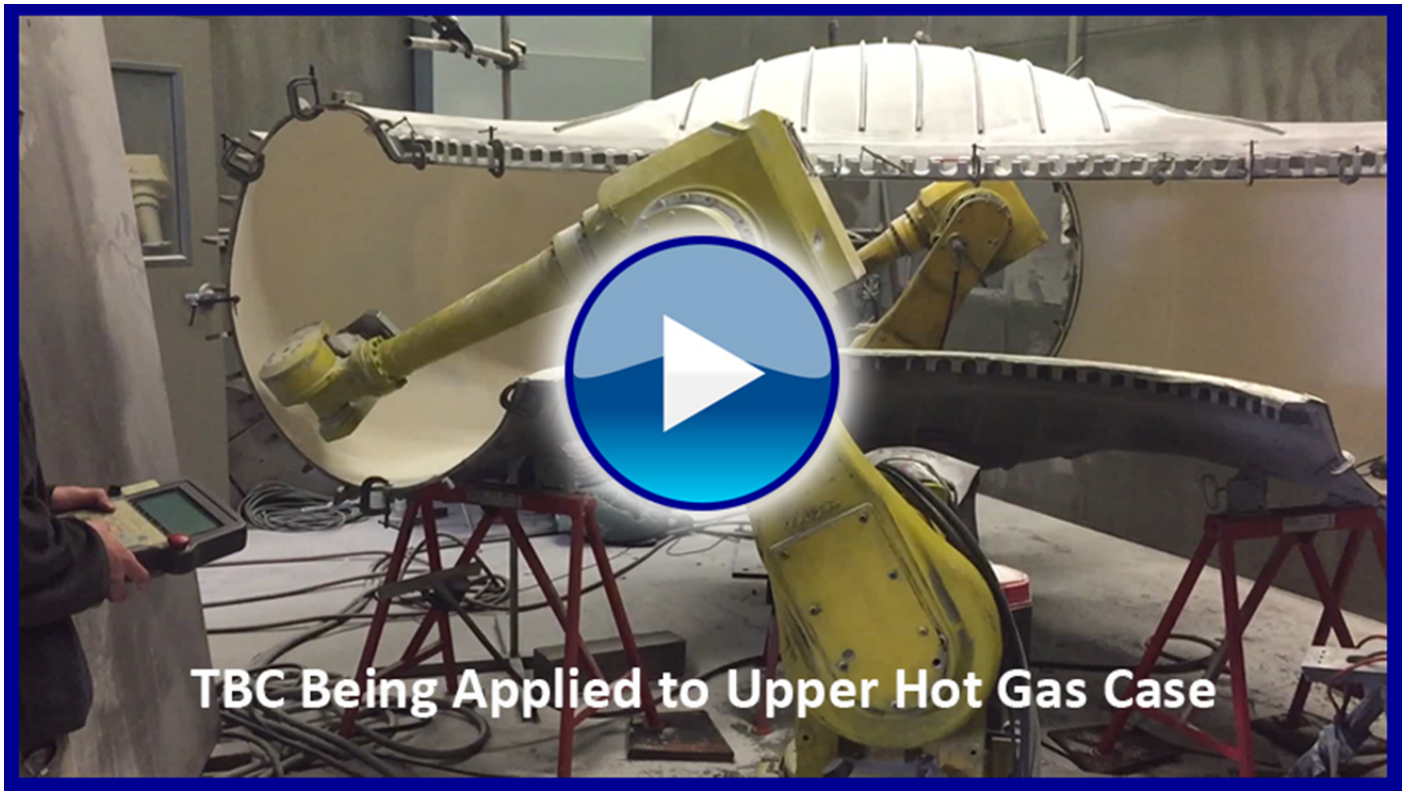


Coating

- Selection of Coating System



Coating



Questions?

- Why?
- When?
- What?
- Where?
- How?