GTEN 2019 Symposium

October 21-23, 2019 | Banff, Alberta

Gas Turbine Repair Metallurgy

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Presented at the Gas Turbines Energy Network (GTEN) 2019 Symposium

Banff, Alberta, Canada - October 2019

Agenda

- Additional Reading
- Why repair gas turbine components?
- Materials
- Metallurgical Analysis Case Studies

Additional Resources

- www.gten.ca

RESOURCES FROM EVENTS:

2018 GTEN WORKSHOP

Presentations

- GT Basics and Unit Types, Applications
- HRSGs, Combined Cycles and Cogeneration
- Flexibility with Renewable Energy
- Natural Gas Pipeline Compression
- Capital and O&M Costs
- GT Combustion and Emissions
- Standards for GHG and Air Pollution Emissions
- Panel Discussion: Clean Energy Synergies and Tradeoffs - Rainer Kurz
- Panel Discussion: Clean Energy Synergies and Tradeoffs - Manfred Klein
- Panel Discussion: Clean Energy Synergies and Tradeoffs - Amanda McAlorum

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2017 IAGT SYMPOSIUM

Papers

- 17-IAGT-101 - SGT-750 Fuel Flexibility, Engine and Rig Tests
- 17-IAGT-102 - (Presentation Only)
- 17-IAGT-103 - Titan 250 Gas Turbine Development
- 17-IAGT-104 - Siemens Introduces the SGT-A45 Mobile Unit: Superior Performance with Trusted Technology

Additional Resources

18TH SYMPOSIUM OF THE INDUSTRIAL APPLICATION OF GAS TURBINES COMMITTEE
BANFF, ALBERTA, CANADA
OCTOBER 19-21, 2009

IAGT™

2009-IAGT-303

THE ROLE OF METALLURGICAL ANALYSIS IN GAS TURBINE MAINTENANCE

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Keywords: *Metallurgical Life Analysis, Reparability, Maintenance*

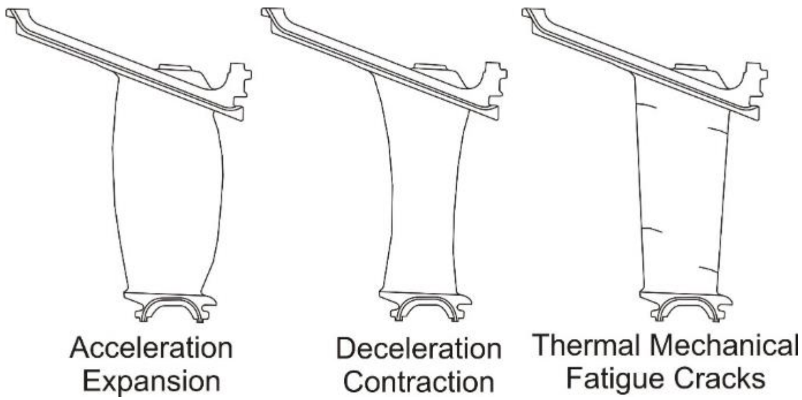
Abstract

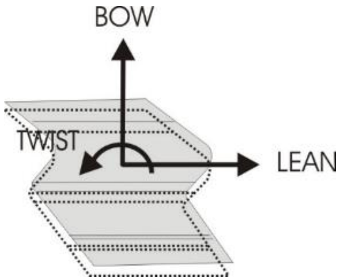
Metallurgical analysis of gas turbine blades to characterize component degradation can be used to assess the reparability of the blades, identify abnormal or detrimental engine operating conditions and define the potential for service interval extension. The following paper summarizes the role of metallurgical analysis in managing the operation and maintenance of turbine blades to reduce costs and improve reliability. The implications of various types of damage on operation and maintenance, including material degradation, coating degradation, hot corrosion, impact damage and damage within the internal passages will be discussed.

Why repair gas turbine components?

- 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

What gets repaired?

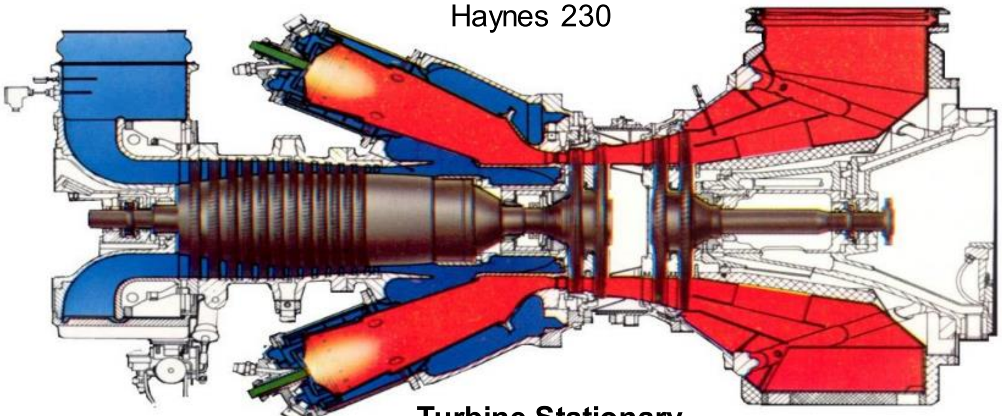




What are the materials?

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

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



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

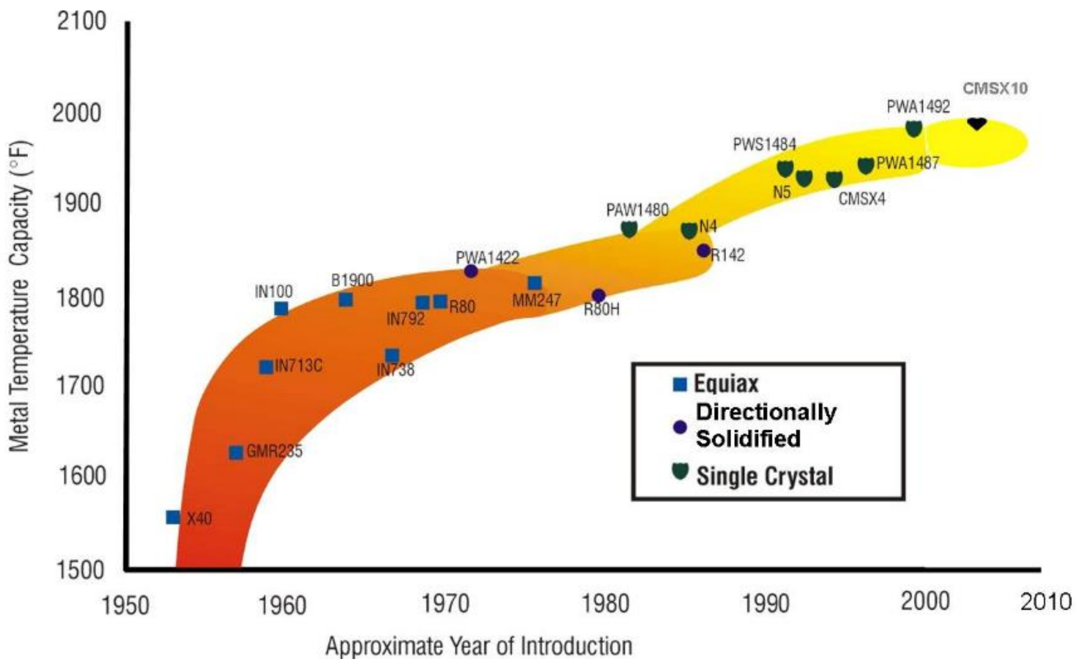
Compressor Casings
Grey Cast Iron
Carbon Steel
Aluminum

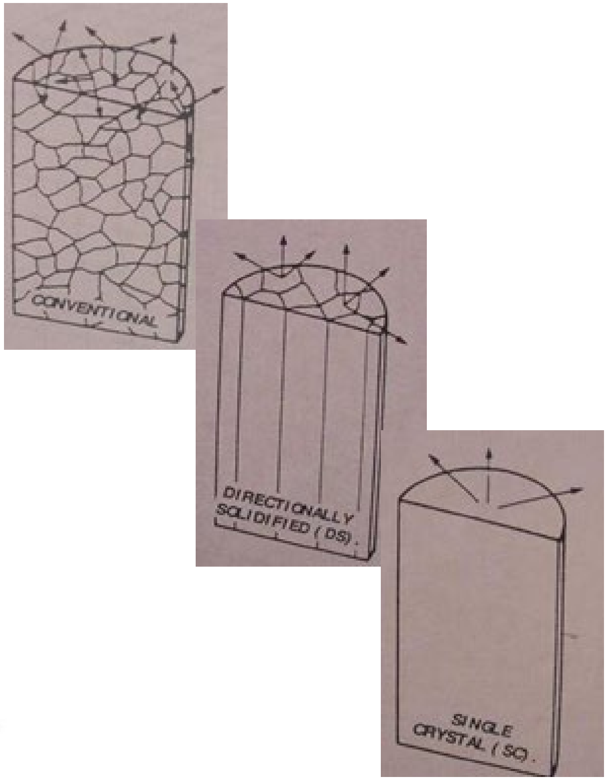
Turbine Shells
Ductile Cast Iron
Stainless Steel
Nickel Alloy

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

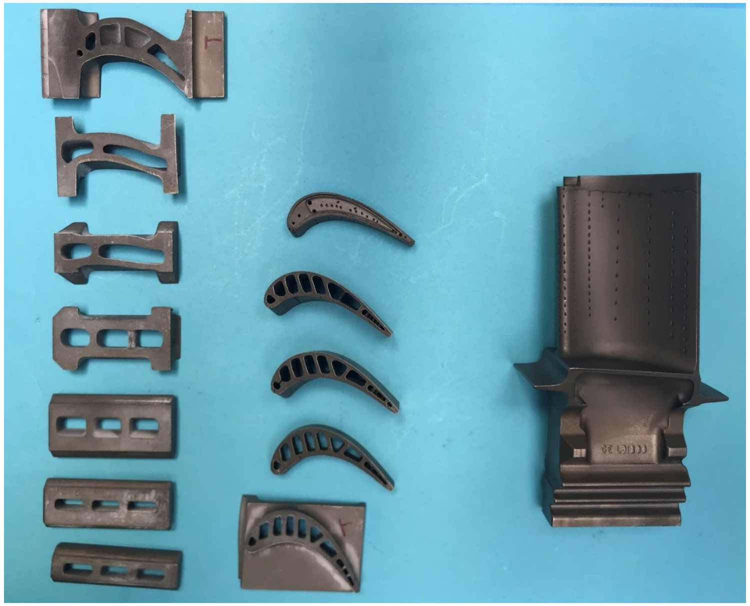
What are the Materials?





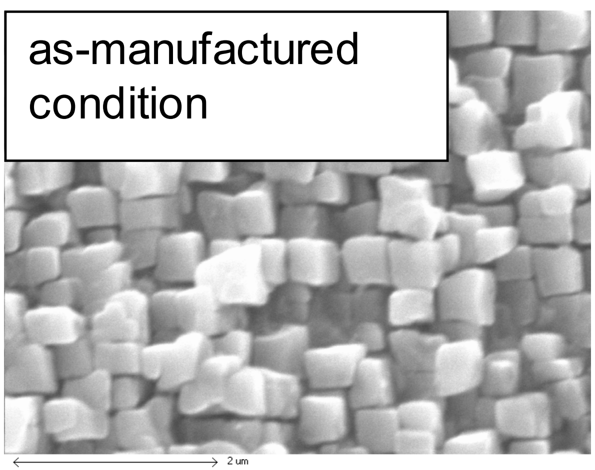
Gas Turbine Blades

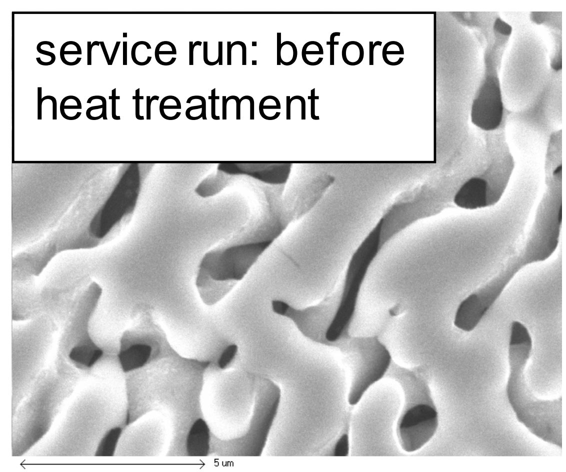
- Operate in high temperature and high stress service
- Each blade extracts as much power as a race car engine



Superalloys

- Y’ structure provides nickel alloys strength at high temperature
- This structure degrades over time reducing strength of material





Metallurgical Analysis

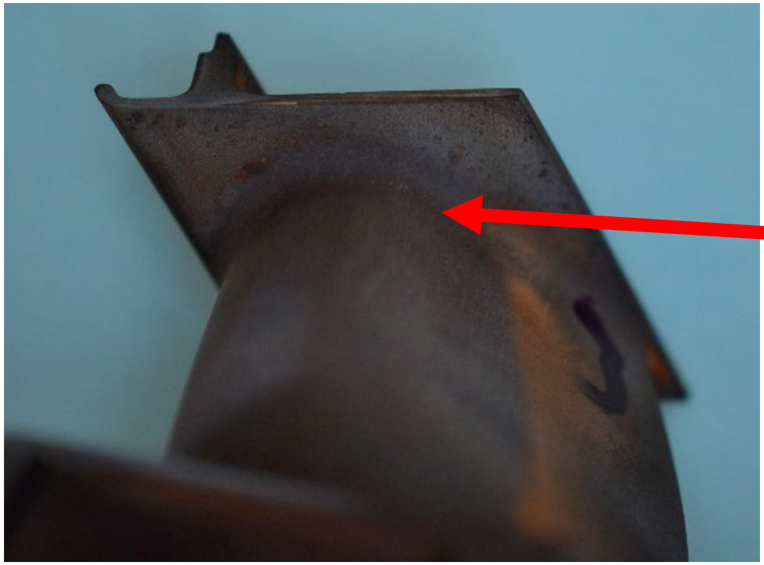
- Predominantly a destructive analysis of one or more turbine blades to identify issues not detectable using traditional non destructive testing (NDT)
- Evaluate microstructure
- Evaluate internal surfaces and features
- Investigation of indications found by NDT

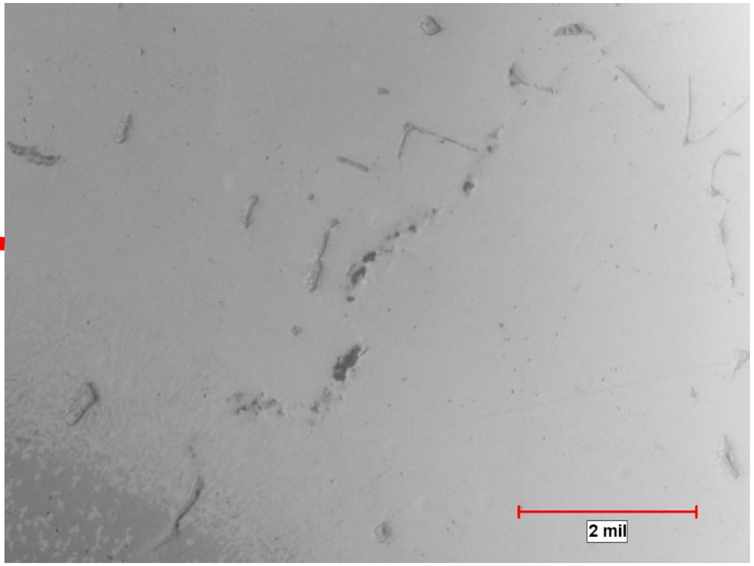
Metallurgical Analysis Case Studies

- A selection of recent metallurgical findings on various gas turbine components
- Investigation of indications discovered with traditional NDT
- Discovery of conditions that typical NDT would not detect

SGT100 HPT Blades

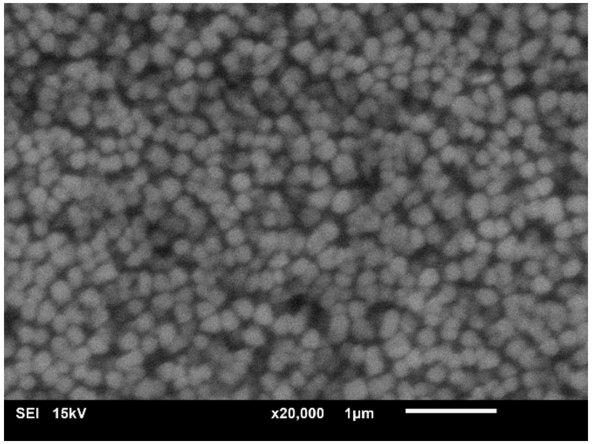
- Creep voiding in the shroud/ airfoil radius



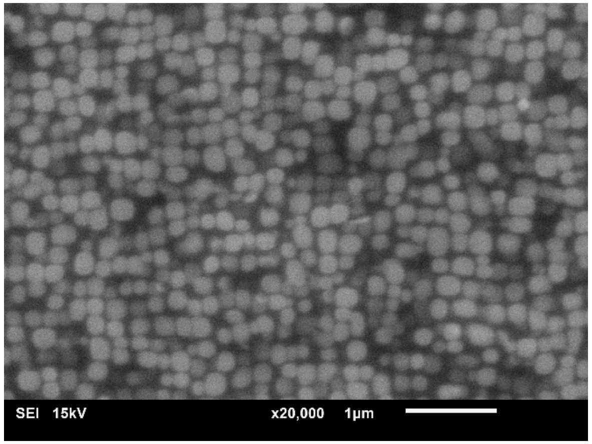


SGT100 HPT Blades

- No overaging of the microstructure – voiding due to excessive stress
- Modification of the shroud required to reduce cantilevered load (stress)



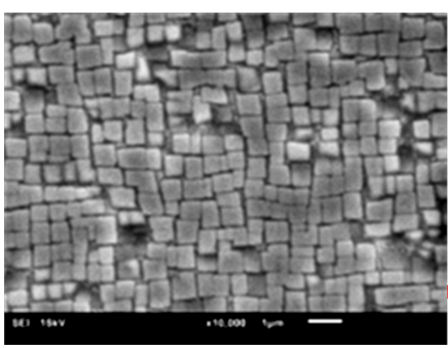
Root

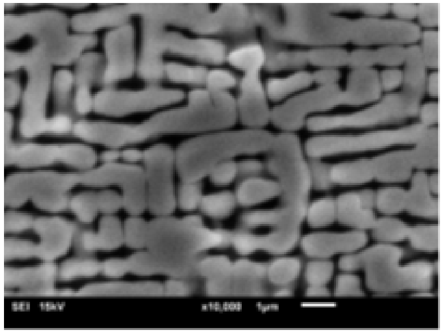


Airfoil

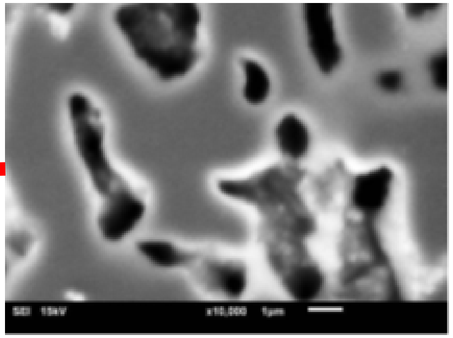
SGT-A35 24G HPT Blades

- Extent of over-aging after 24k hours greater than mean aging from prior analyses of component, suggesting higher than nominal temperature.
- Rejuvenation applied earlier than typical (48k hours)





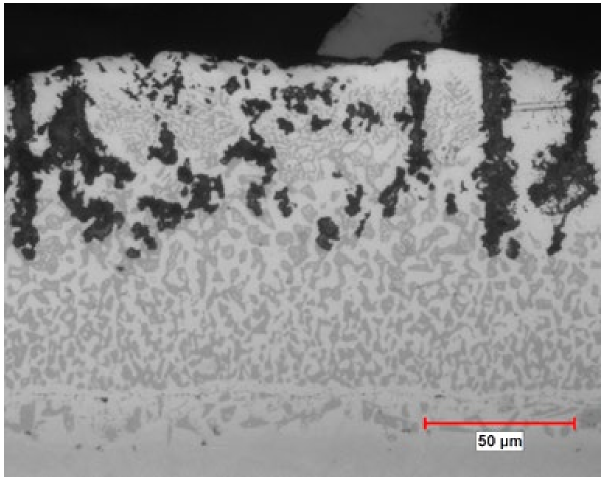
Mean aging after 24k hours

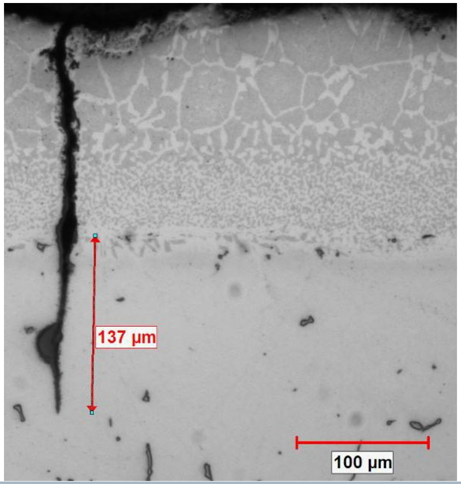


Root

GE LM2500 HPT1 Blades

- ‘marinized’ coating (CoCrAlY outer layer; CoNiCrAlY inner layer) identified.
- Cracking mostly confined to outer CoCrAlY outer layer, but also penetrated into the base material.



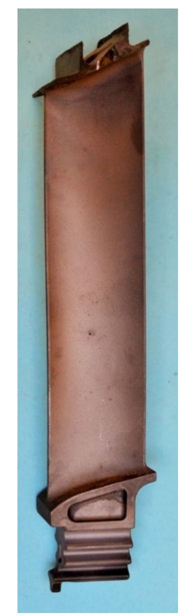


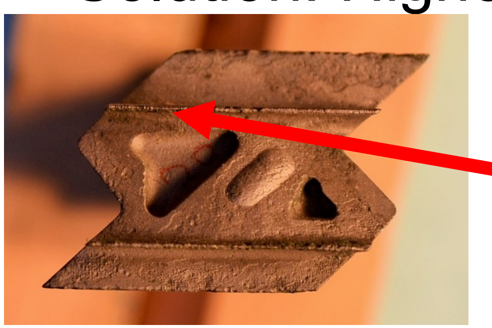
GE LM2500 HPT1 Blades

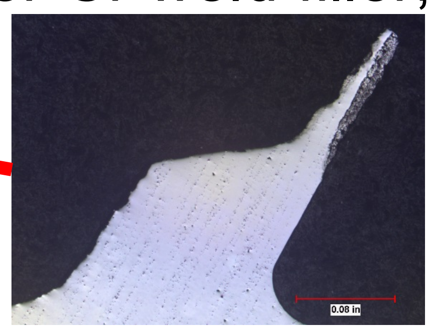
- CoCrAlY's have optimal hot corrosion resistance but prone to cracking (brittle).
- Pt-Al coating substituted for crack resistance and acceptable hot corrosion resistance

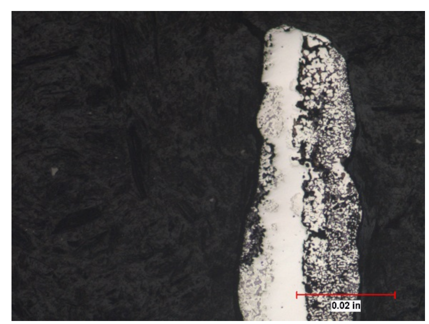
GG8 Stage 2 turbine blades

- Significant Type-I (high temp) hot corrosion damage of seal fins identified. PWA1484 (single crystal) base alloy prone to hot corrosion attack (low Cr).
- MCrAlY coating applied to airfoil but not outer shroud surfaces
- Solution: Higher Cr weld filler; MCrAlY shroud







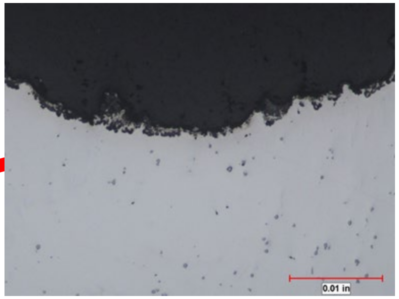


GT8B Stage 1 Blades

- Tip material loss due to oxidation. Previous repair weld filler material identified as IN625 which has relatively low oxidation resistance.
- Upgrade to oxidation resistant weld filler to better maintain tip clearance

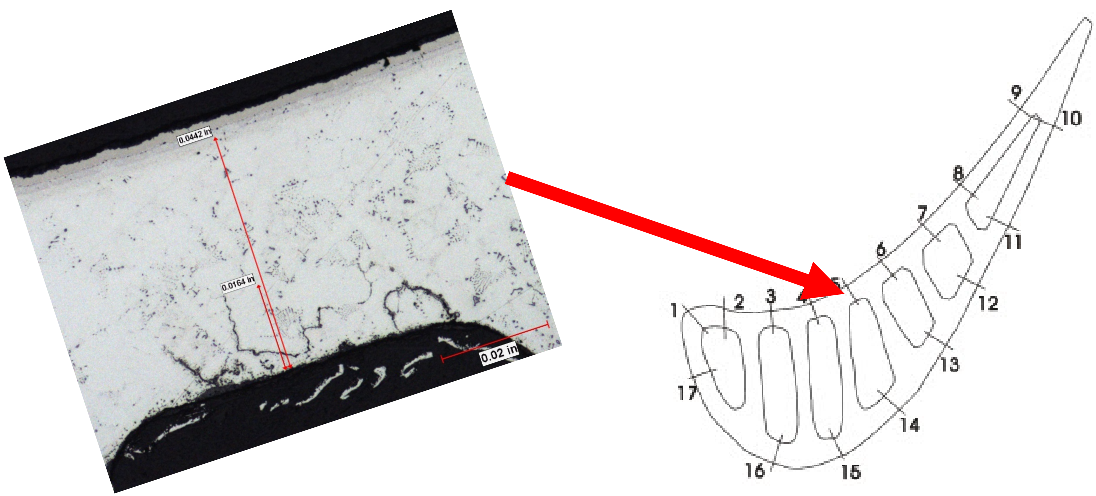
GE Frame 7EA Stg 1 Bucket

- Poor internal coating coverage – likely as-manufactured condition, as bare surfaces had only minor oxidation damage.
- Internal coating to be replaced, but regions of oxidized base material may have less than ideal coating so continued monitoring required



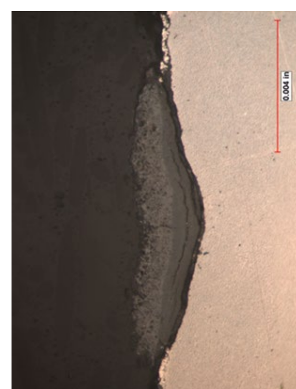
SGT-A35 24G HPT Blades

- Intergranular oxidation (up to 0.017-inches) of internal airfoil surfaces, significantly deeper than observed in prior analyses.
- Blades retired from service



Trent 700 IPT Blade

- Shank surfaces not coated. Type-II (low temp.) hot corrosion pitting observed. Base alloy (CMSX-4 – single crystal) prone to hot corrosion (low Cr).
- Si-Al aluminizing recommended for shank and under-platform surfaces.



Summary

- Gas turbine blades tell us a story about their service
- Metallurgical analysis is an important tool to inspect for conditions not detectable using external inspection, investigate indications found with traditional NDT and confirm and verify repair methods

Gas Turbine Repair Metallurgy

Any Questions?