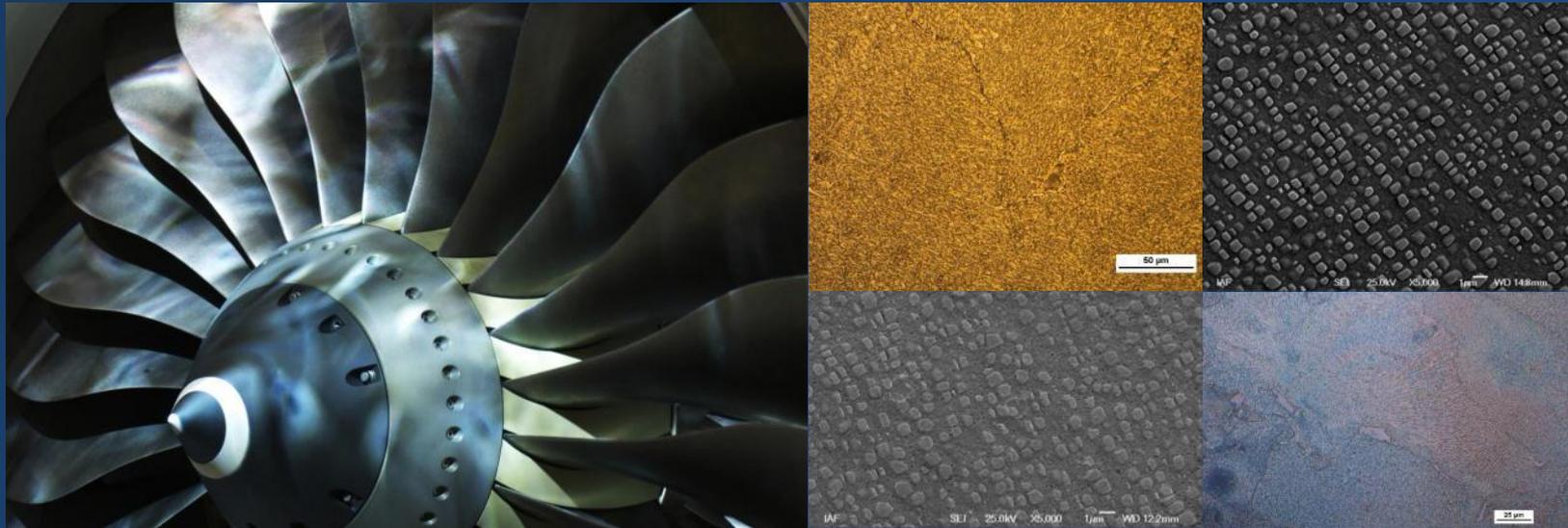


# OT or Not?



Issues Concerning Over-temperature of Turbine's Blades

Capt. Nitzan David Foucks, Materials Div., IAF

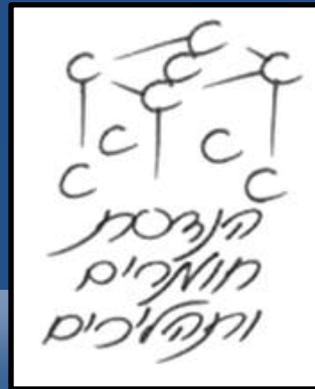
# Table of contents

- Background:
  - Materials and process department, IAF
  - Inspection and Failure analysis of turbine blades
  - Metallurgy of Nickel-based super alloys
- Over-temperature (OT):
  - What is OT?
  - Effects of OT
- Looking for OT:
  - Microscopic examination
  - OT or not? Examples



# Materials and process department, IAF

- M&P department was established to handle all metallurgical processes, issues and projects in the IAF
- The department conducts **Quality assurance of items, metallurgical inspection of T-64 engine blades, and metallurgical failure analysis**
- In conducting inspection or failure analysis of engine blades, one meets the term “OT”



# OT?

- Each jet engine has an upper temperature limit, defined by the manufacturer
- Above that, an Over-Temperature (OT) inspection is required
- In failure analysis, the blades of the failed engine are inspected for OT

## What is OT?

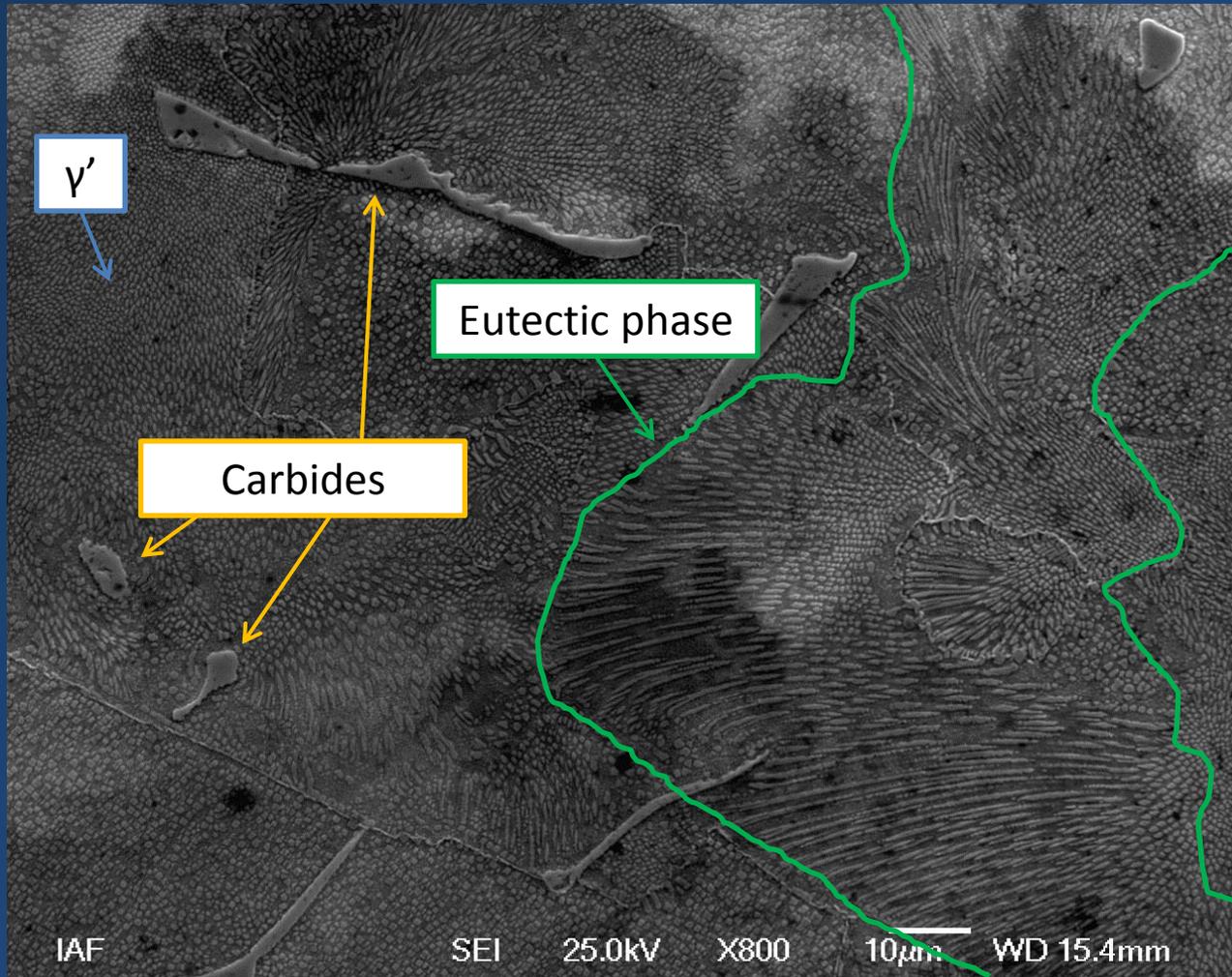


# Metallurgy of Nickel-based super alloys

- Nickel-based super alloys show high strength, high fatigue life and excellent corrosion resistance at **high temperatures**
- These qualities are the result of the alloys' complex microstructure



# Inconel 738 as an example



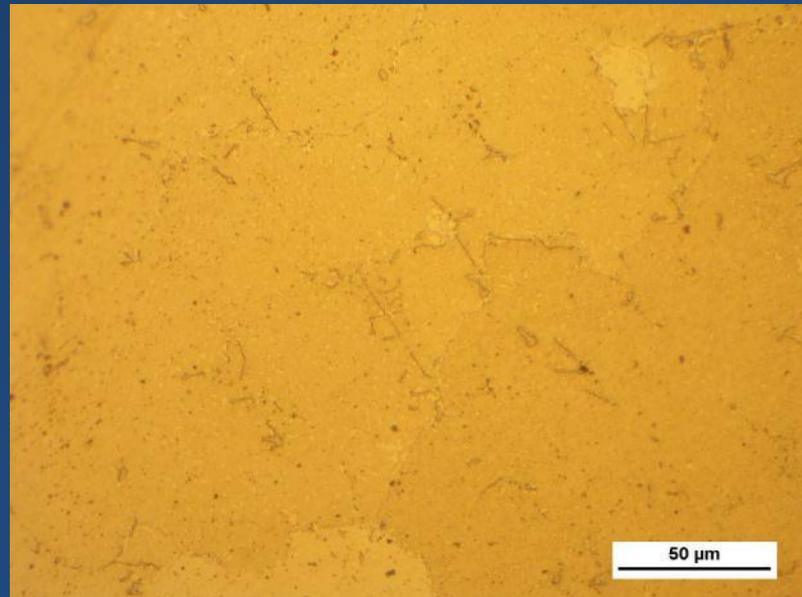
# What is OT?

- In order to achieve the microstructure shown, the alloy will go through two thermal processes: solution treatment and aging



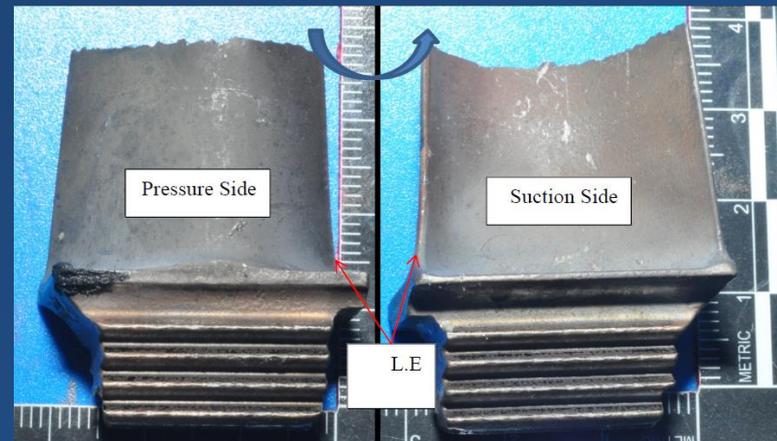
# What is OT? (cont.)

- OT happens when the alloy is exposed to temperatures similar to those of the solution treatment, in an uncontrolled way
- **The Microstructure is changed!**



# Effects of OT

- Changes in the microstructure can cause:
  - Hot corrosion attack
  - Decreased fatigue life
  - Creep
  - **Failure**



# Short Summary

- What we learned so far:
  - OT is caused when a nickel-based superalloy is exposed to high temperatures ( $\sim 1000^{\circ}\text{C}$ )
  - OT can lead to failure of the Jet engine
- How can we know if a blade underwent OT?



# Microscopic inspection for OT

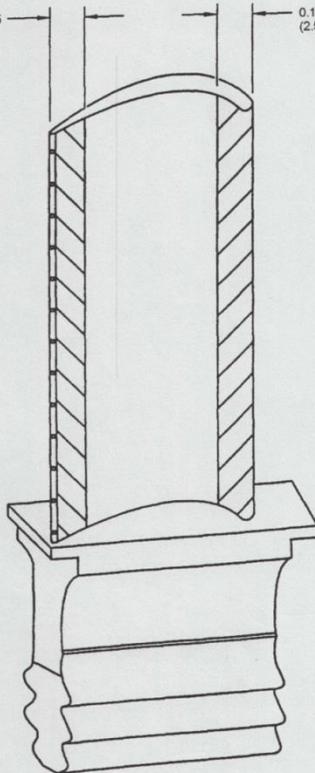
- OT can lead to failure because of changes in the microstructure
- **In some cases**, Manufacturer's technical guide will call for a metallurgical cross-section and microscopic (optical/SEM) examination
- Some guides will also include reference pictures, in order to evaluate the change in microstructure



# Example: OT inspection in a T-64 engine

0.12-0.15  
(3.0-3.8)

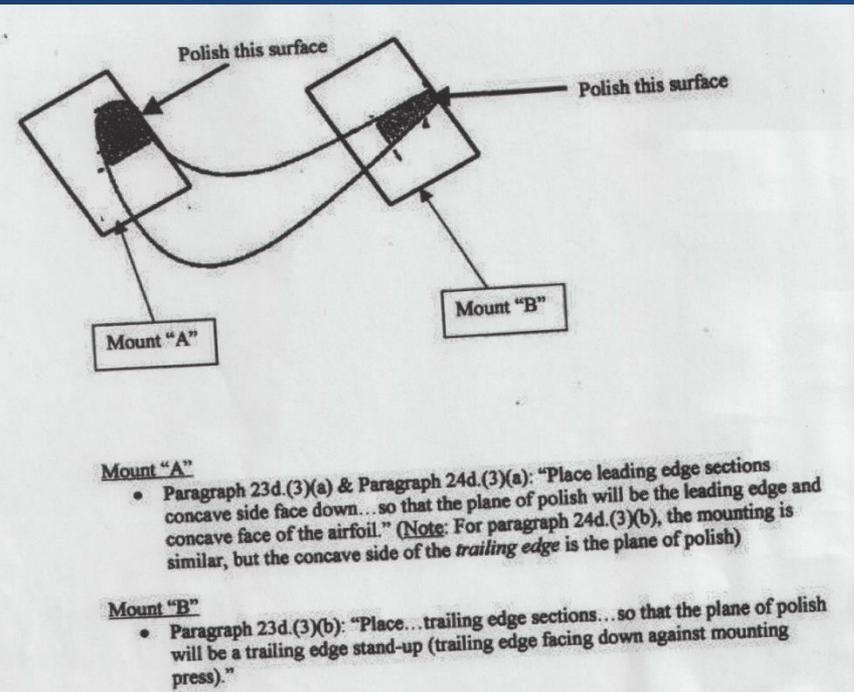
0.10-0.11  
(2.5-2.8)



ALL DIMENSIONS ARE IN  
INCHES WITH MILLIMETERS  
IN PARENTHESES

024003

Figure 5. Sections for T64 Stage 1 Blade Overtemperature Inspection



# Example: OT inspection in a T-64 engine

NAVAIR 02B-105AJB-6-2  
T.O. 2J-T64-13

024 00

Page 17

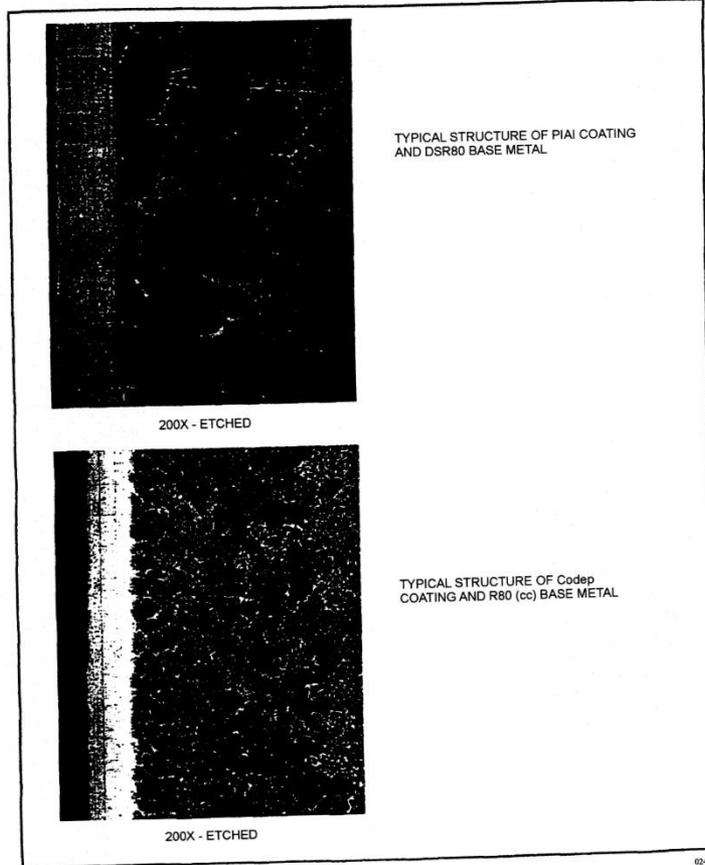


Figure 7. Metallographic Examination - REJECTABLE (Sheet 2 of 3)

NAVAIR 02B-105AJB-6-2  
T.O. 2J-T64-13

024 00

Page 20

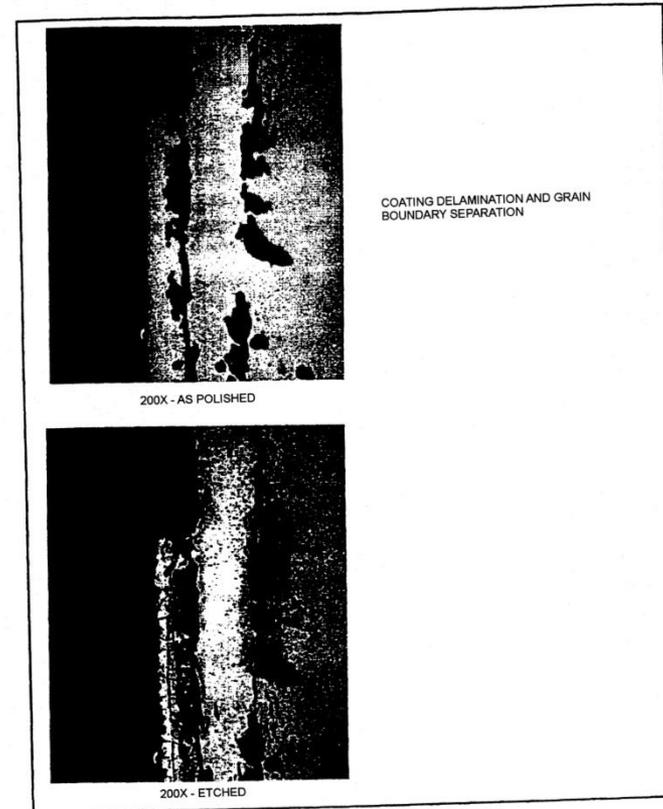
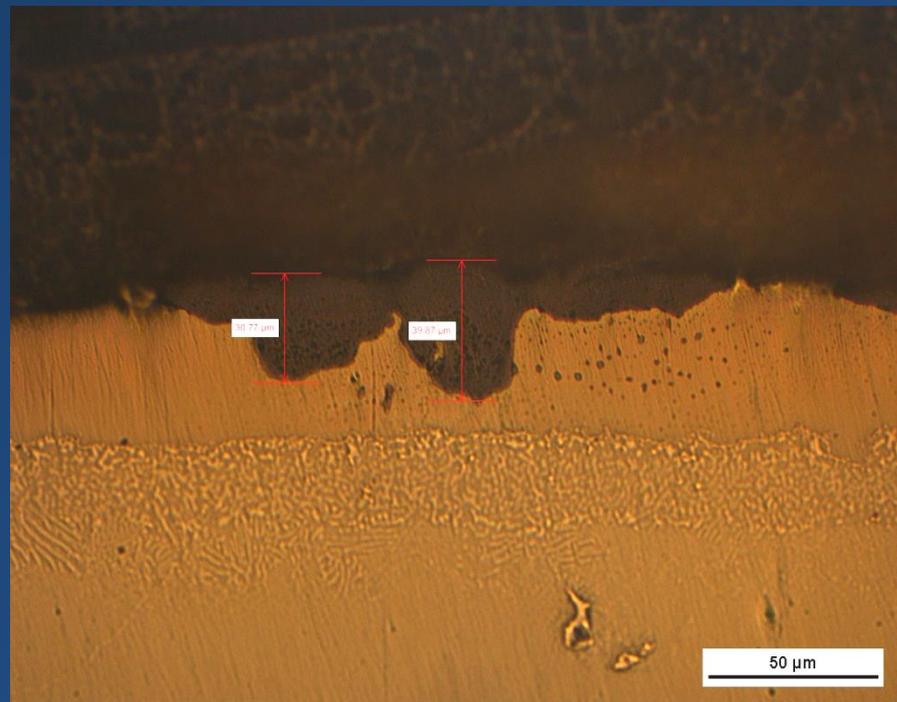


Figure 8. Metallographic Examination - REJECTABLE (Sheet 2 of 5)



# Example: OT inspection in a T-64 engine



# Possible issues

- No technical guide for OT inspection
- No reference photos for evaluating the results
- A very qualitative testing – based mainly on visual examination

How can one handle these issues?



# First case: FA of JT3D engine (Boeing 707)

A very qualitative testing – based mainly on visual examination



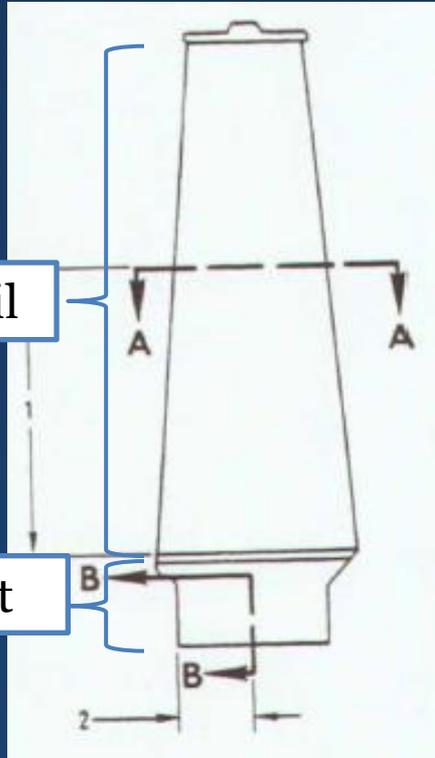
# First level



כיוון טיסה



# Manufacturer's guide

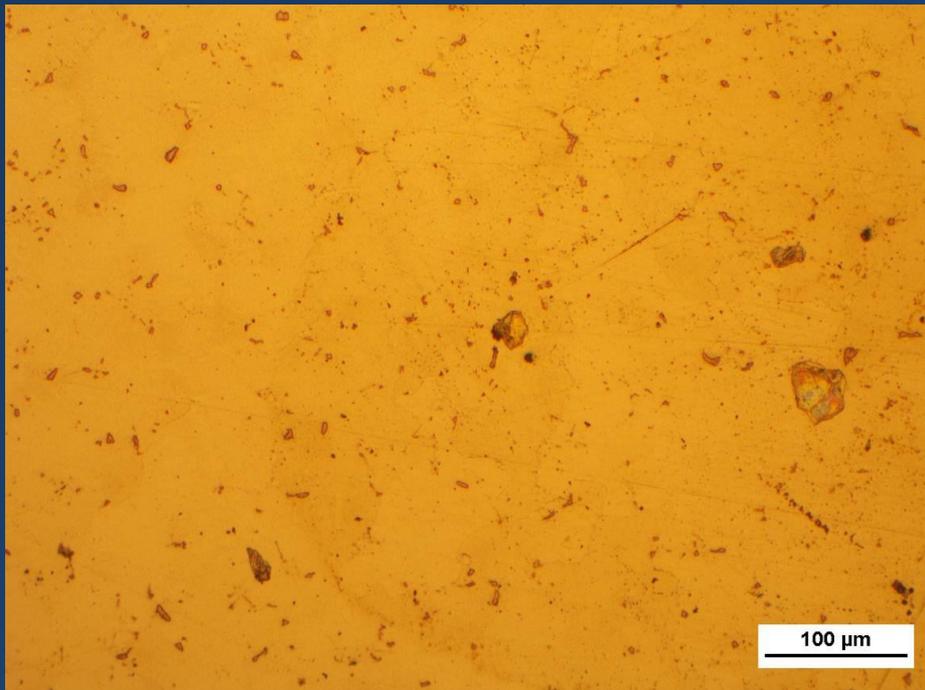


PWA 1455 Material After Attaining Metal Temperature of Less than 2000°F (1094°C) Exhibiting Typical Uniform Array of Matrix Gamma Prime Precipitate (Circled Areas), Gamma-Gamma Prime Eutectic Islands (A), and MC-type Carbides (B)  
Figure 1 (1000X)

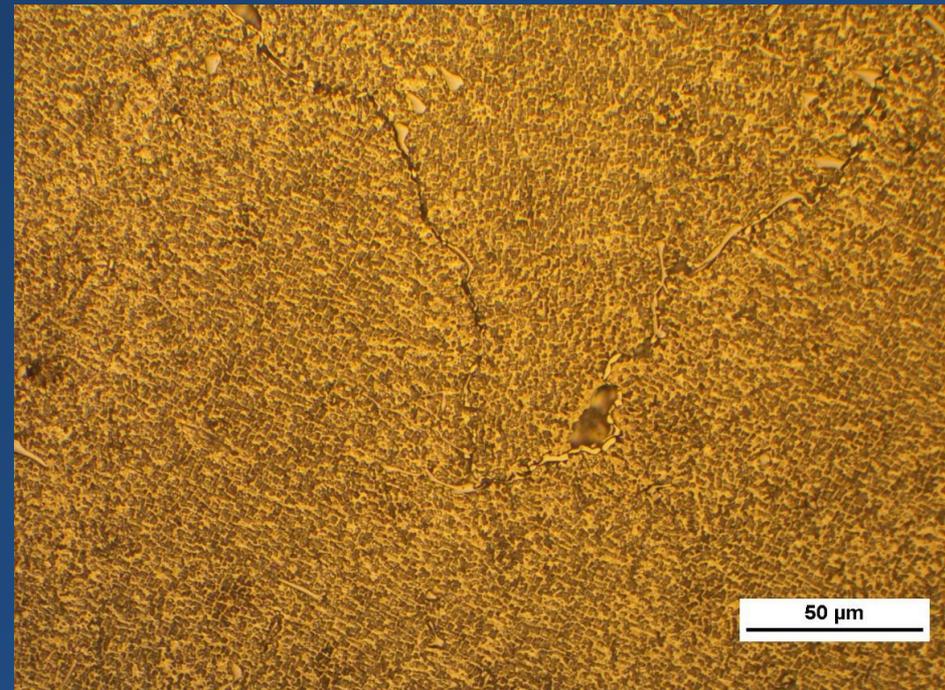
- In order to determine if there is OT, the microstructure of the root is compared to the microstructure of the airfoil



# Results



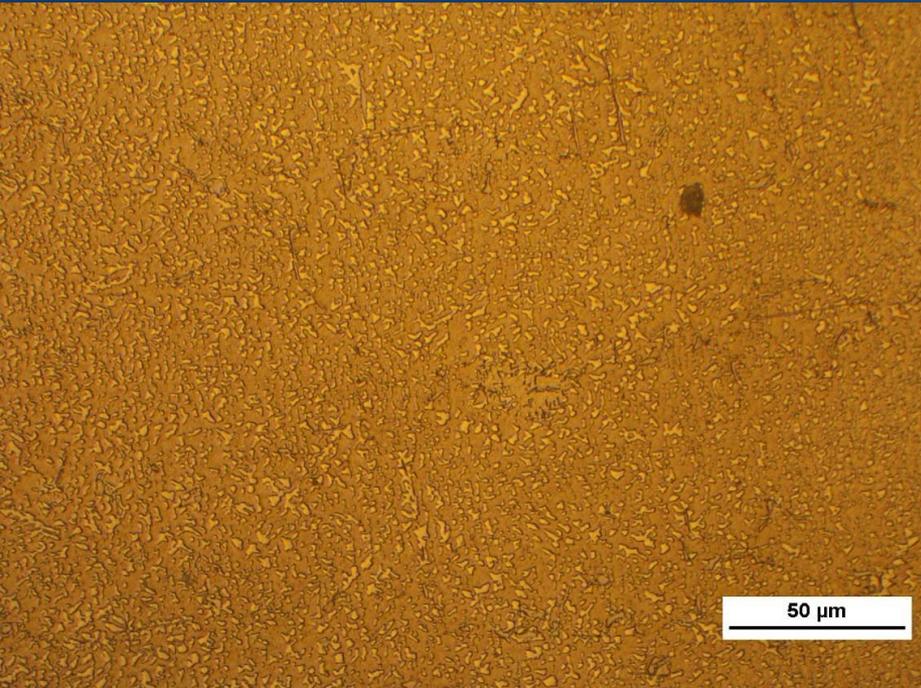
Airfoil - OT



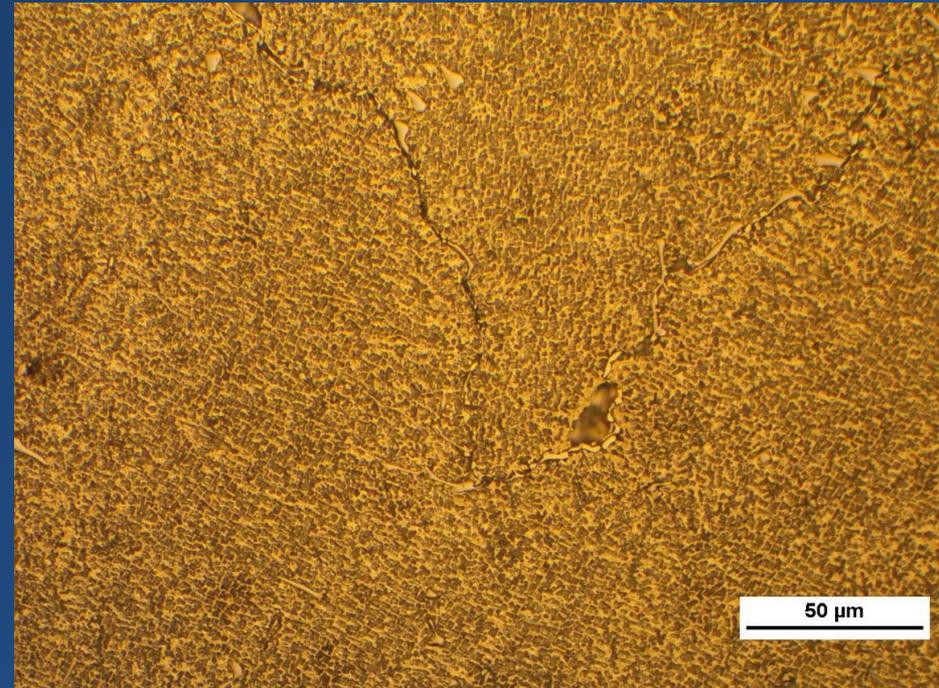
Root - No OT



# Results (cont.)



Center of Airfoil - ?



Root - No OT



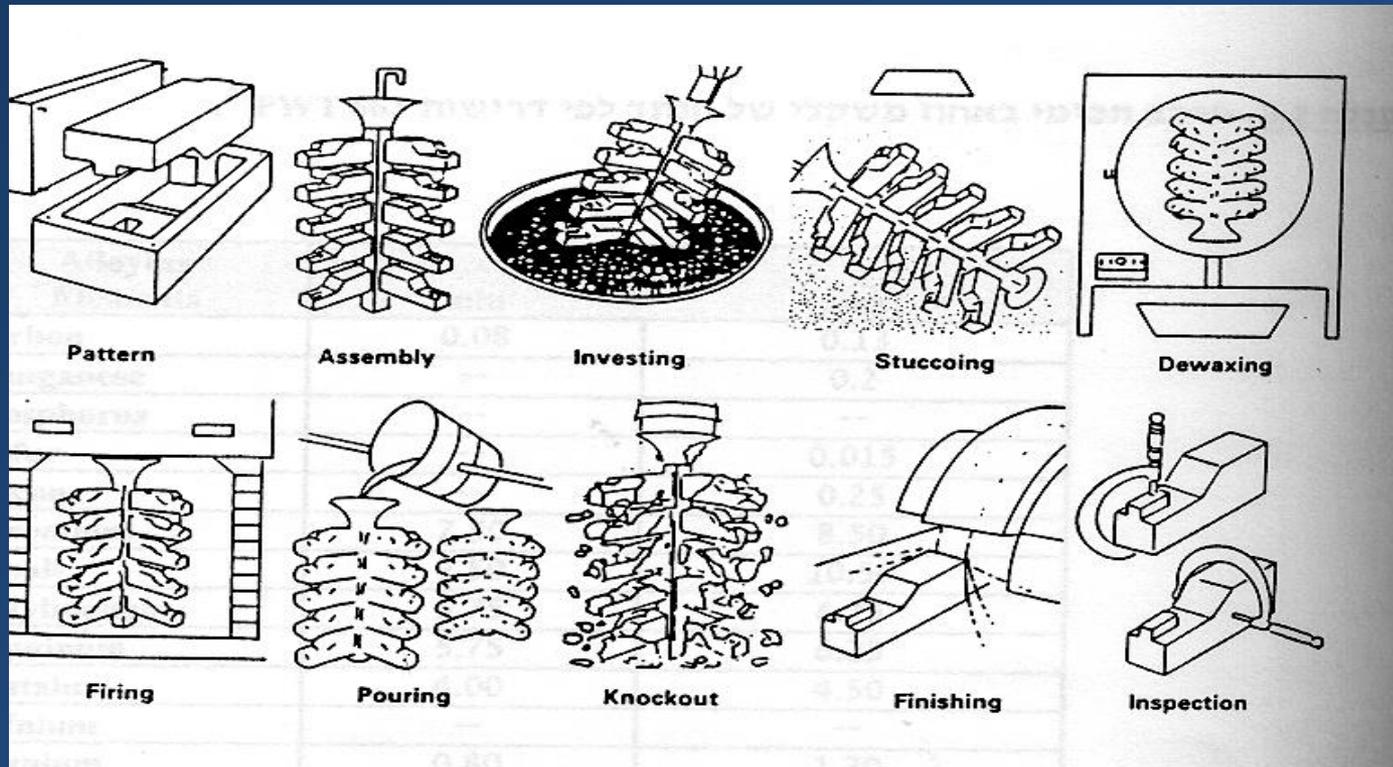
# Conclusions

- The M&P dept. position: The airfoil and the center of the airfoil has undergone OT
- The manufacturer's response: OT in the airfoil, no OT in the center of the airfoil but **time-dependent change** of microstructure



# Other causes of change in microstructure

- Service time
- Manufacturing process - casting



# The quality assurance “itch”

- In quality assurance, any deviation from the standard is considered a flaw
- In examining blades’ microstructure, a deviation is not necessarily a flaw (OT)
- Because of the qualitative nature of the examination, one should be **very** conservative



# Second case: T-56 engine (C-130 Hercules)

- No technical guide for OT inspection
- No reference photos for evaluating the results



# Third level

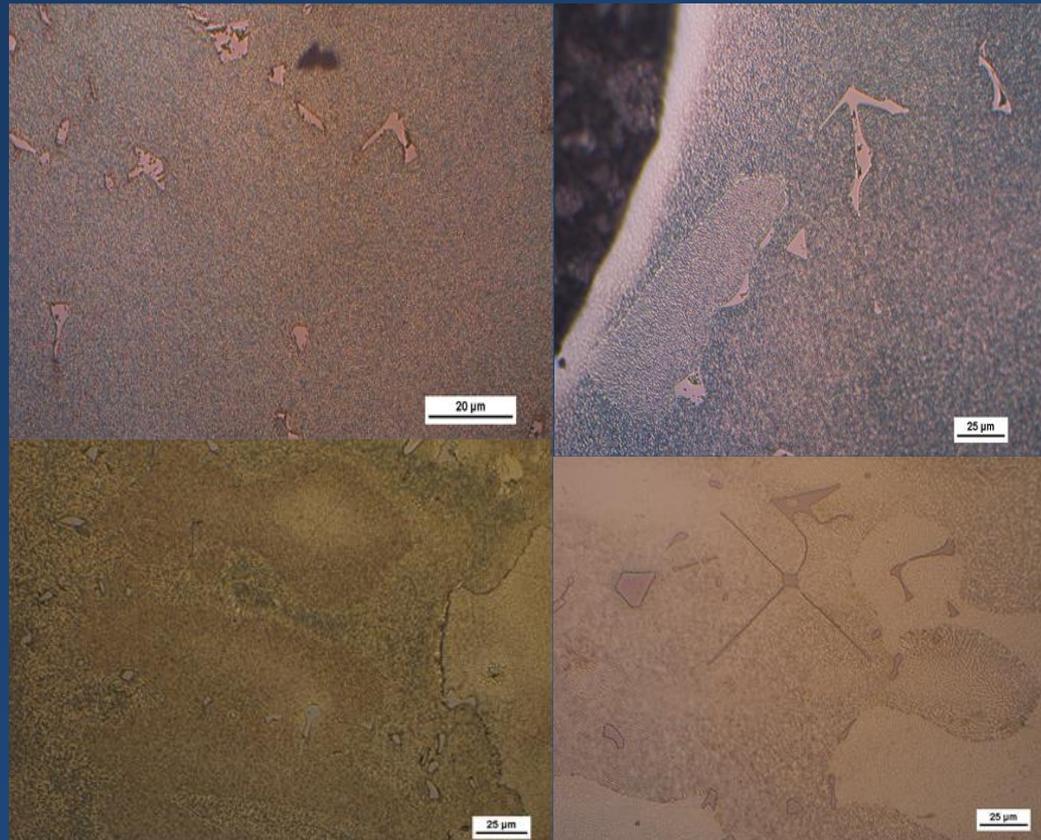


# Testing method

- The IAF had no technical guide for evaluating OT of the blades
- M&P dept. decided to conduct a similar inspection to the one in the JT3D engine, taking metallurgical cross-sections in the airfoil and root of the blade



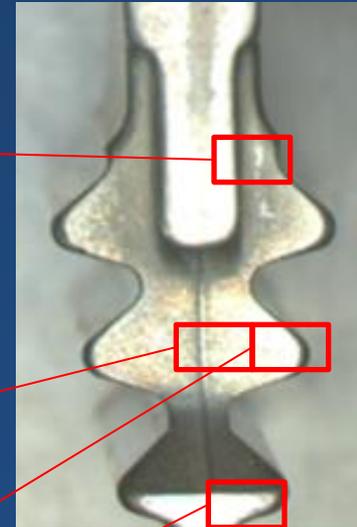
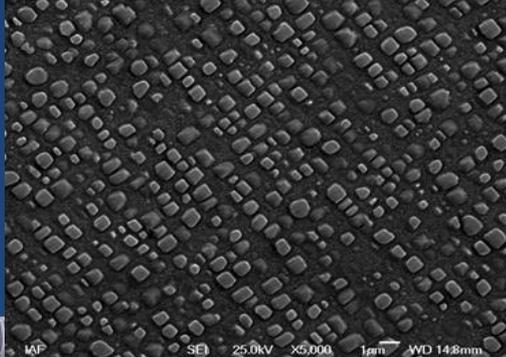
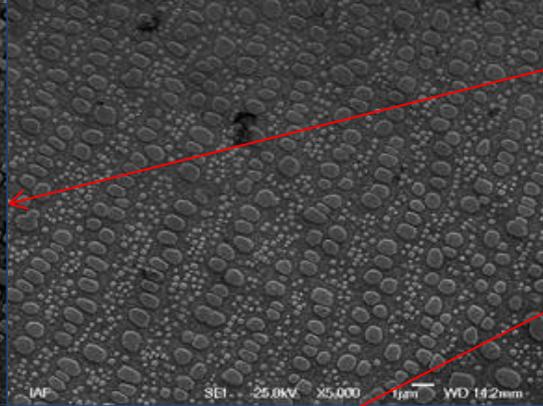
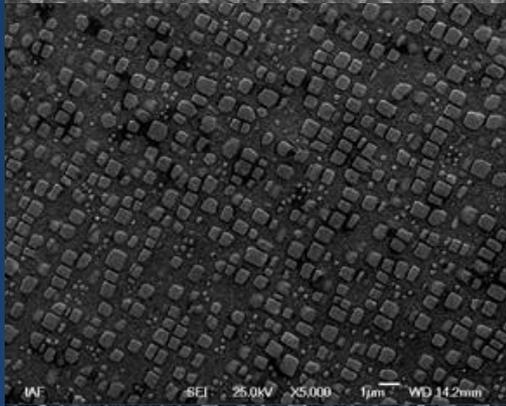
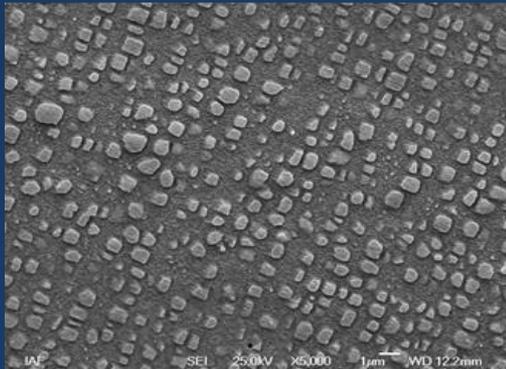
# Results



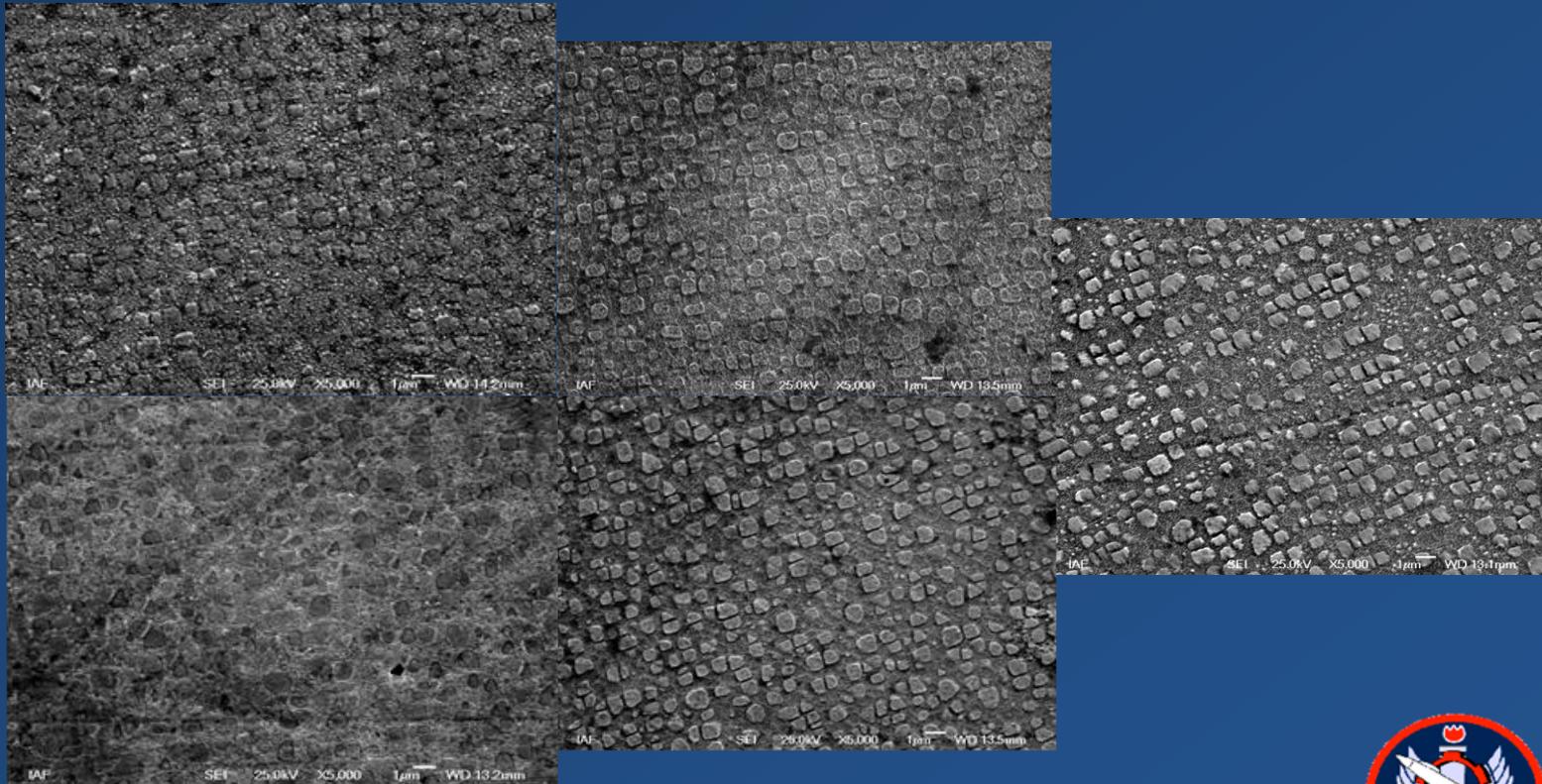
Microstructure of roots from 4 different blades



# Results (cont.)

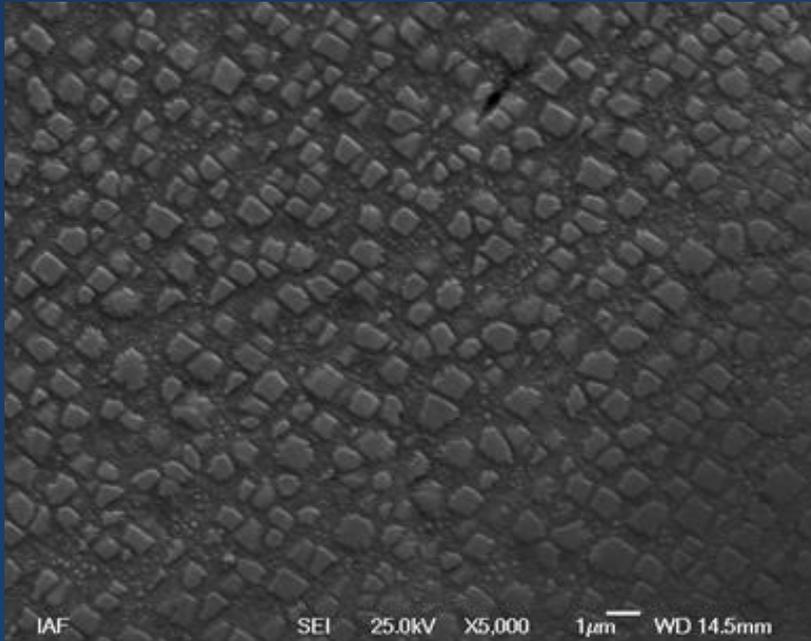


# Results (cont.)

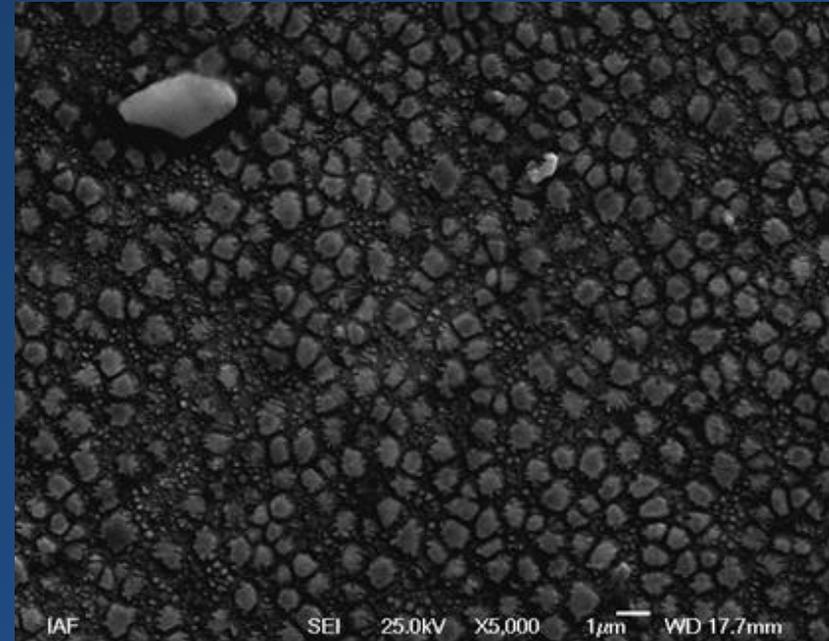


# Results (cont.)

Root



Airfoil



# Conclusions

- There are changes in the microstructure, but they do not result from OT
- The probable causes for the changes might be due to casting or time-dependent changes
- IAF conclusion: No OT
- Manufacturer conclusion: No OT



# Final thoughts

- OT examination requires more than just visual examination
- It is based on prior OT examinations, along with an understanding of the production process and service of the specimens



# Questions?



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א"א 22 - האומנות שבתעופה



Thank you!



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א"א 22 - האומנות שבתעופה

