OT or Not?

Issues Concerning Over-temperature of Turbine’s Blades

Capt. Nitzan David Foucks, Materials Div., IAF
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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”
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

Eutectic phase
Carbides
\( \gamma' \)
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 (~1000°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

Mount “A”
- Paragraph 23d.(3)(a) & Paragraph 24d.(3)(a): “Place leading edge sections concave side face down...so that the plane of polish will be the leading edge and concave face of the airfoil.” (Note: For paragraph 24d.(3)(b), the mounting is similar, but the concave side of the trailing edge is the plane of polish)

Mount “B”
- Paragraph 23d.(3)(b): “Place...trailing edge sections...so that the plane of polish will be a trailing edge stand-up (trailing edge facing down against mounting press)”
Example: OT inspection in a T-64 engine
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
• 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
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
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.)

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?
Thank you!