Developing component upgrades for TBO extension strategies

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TBO extension

Introduction

- OEM offer upgrades that are costly and involve replacement of large parts of the turbine.
- As a benefit of these upgrades, TBO can often be extended resulting in lower maintenance cost and less down time.
- Customers often do not require additional output but are interested in extension of TBO without using new parts for the full turbine.

Siemens SGT5-2000E: Version 6/7 to version 8+

Siemens SGT6-5000F: F4 to F5

GE MS6001FA: F.03 to F.05

Alstom GT13E2: MXL to MXL2

TBO extension analysis

Procedure to determine upgrade possibilities

- OEM recommendations regarding design life and interval periods are starting point.
- Damages as described in repair inspection reports after regular intervals give an indication on their condition.
- Temperature distribution in the turbine and type of fuel show the actual conditions components are exposed to during operation.
- Chemical and mechanical properties of base material and coating may not limit the possibilities towards TBO extension.
- Analysis of above points will indicate if components can be exposed to identical conditions in an extended TBO or if upgrades are required.
- Finally, determine which upgrades are necessary to achieve a TBO extension safely.
  - It might not be possible to perform a repair upgrade and that an upgraded new part is required.

TBO extension

Possible conclusions

A. Components can extend a longer service overhaul without upgrade requirement

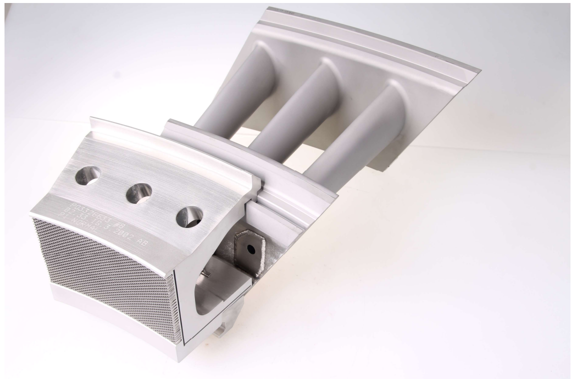
B. Components require an upgrade that can be applied during a repair cycle

C. Components can not be upgraded during a repair cycle and replacement by upgraded new part is required
   - Design upgrade
   - Base material upgrade

TBO extension

A.) Parts do not require modification

- Base material of latter stages of blades and vanes often possess mechanical and chemical properties that are sufficient for exposure to longer period
  - Interval period is based on critical components
- Several combustion components show only minimal damages during the regular intervals and are expected to operate for longer period
  - To monitor components, installation of a combustion dynamics monitoring system can be advised.



TBO extension

B.) Parts can be upgraded during a repair cycle

- If the chemical and/or mechanical properties of the component are limiting the TBO interval or design life of the component no repair upgrade is possible.
- Chemically limiting:
  - Application of corrosion and/or oxidation resistant coating
  - Application of (advanced) TBC to reduce metal temperature
- Mechanical limiting:
  - Application of (advanced) TBC to reduce metal temperature or thermal gradients

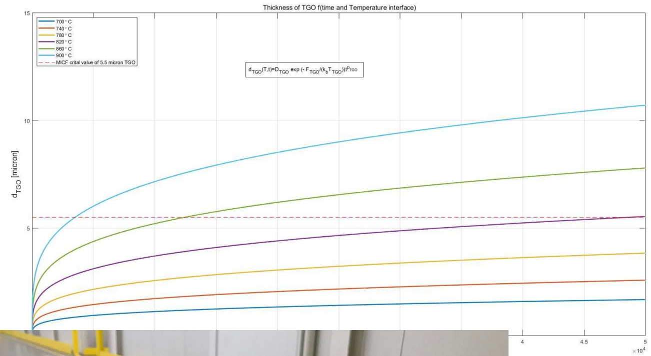
- Application of (additional) coating may not affect behaviour of components
  - Increased coating thickness may not affect throat opening between airfoils in vanes and vane segments
  - Coating systems must be designed for extended TBO interval

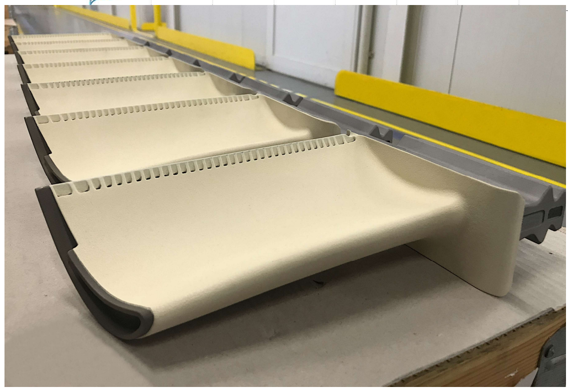
TBO extension SGT5-2000E/V94.2 v6/v7 (50 kEOH)

1st stage blade

Inspection findings

- Physical damages are limited and would not result in premature failure upon further operation.
- However, due to the growth rate of the thermally grown oxide (TGO) between thermal barrier coating (TBC) and underlying MCrAlY, the TBC can fail upon further operation.
- Moreover, further operation beyond 41 kEOH might lead to unrecoverable creep damages. This is valid for both v6 components that are manufactured from cast Inconel 738 and v7 components that are manufactured from cast Rene 80. Although Rene 80 has an increased creep capability up to 10-15 °C, the v7 components experience up to 10 °C higher metal temperatures.





Upgrade solution

- By application of an advanced TBC instead of a standard TBC, the interface temperature between TBC and MCrAlY can be reduced approximately an additional 25 °C and the average metal temperature up to 10-15 °C.
- Such a decrease in metal temperatures will result in an increased creep life and will be doubled approximately. In addition, stable TGO growth is expected for the extended TBO without spallation.

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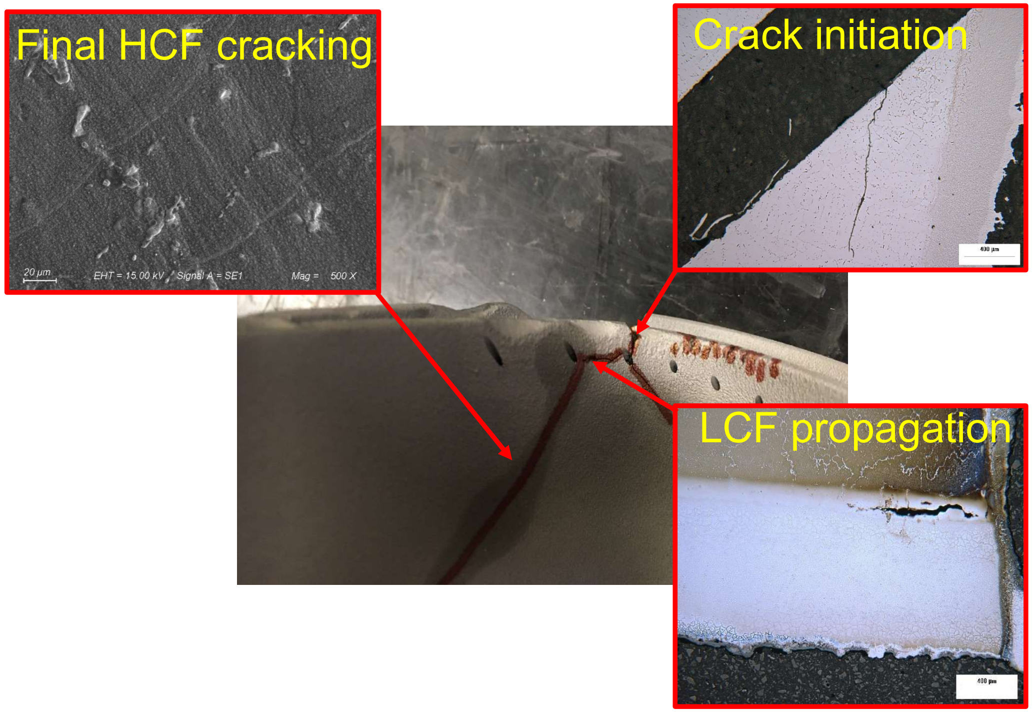
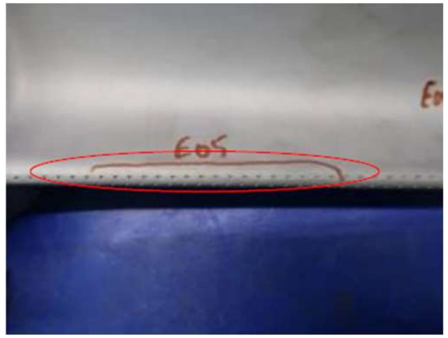
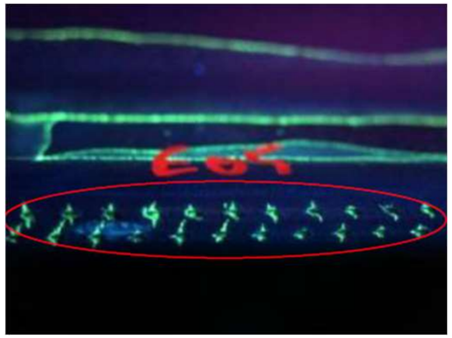
TBO extension

C.) Upgraded new part required

Some components might be degraded/damaged to such an extend during the regular interval, that further operation could lead to premature failure or cannot even meet standard interval period.



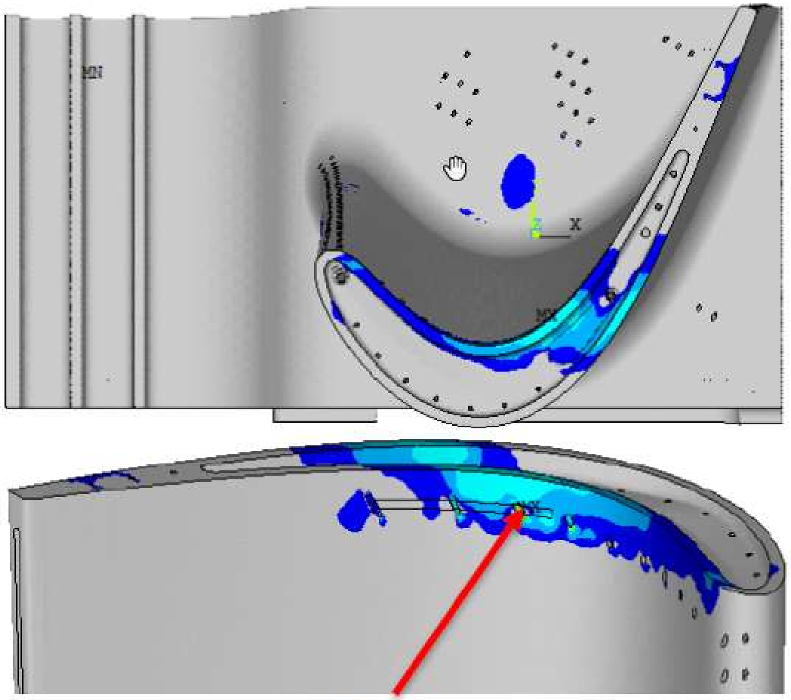




Finite element analysis

Local creep strain at 7th cooling hole

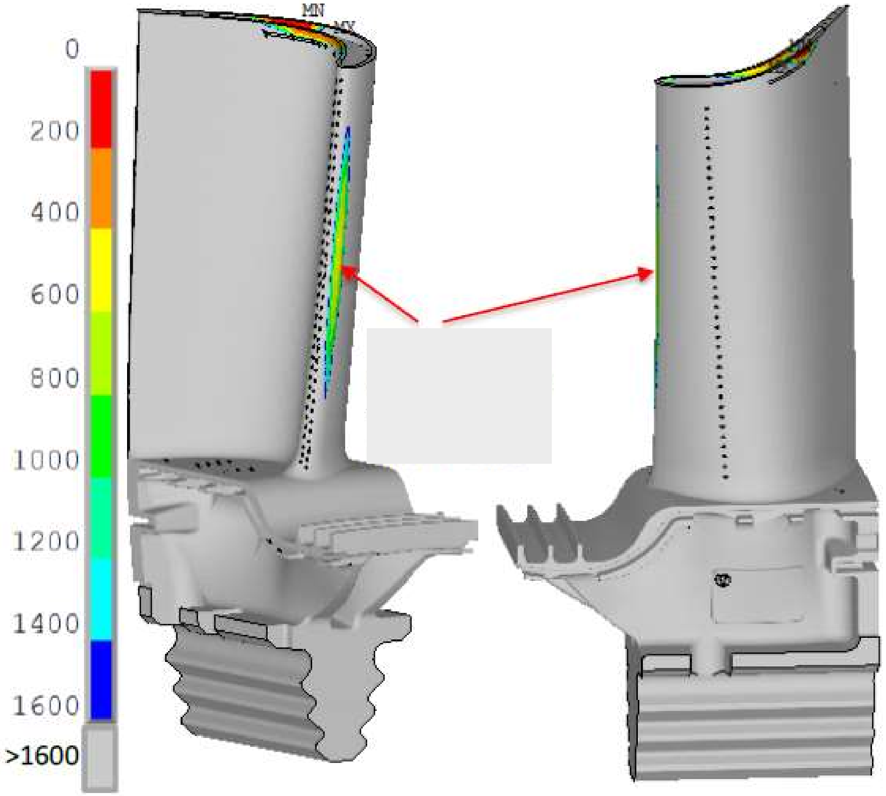
- OEM limitation for maximum local creep strain is set at 1%, while first evidence of creep damage can be observed at 2%
- Maximum strain of **3,6%** is observed in OEM component already early in operation followed by thermal relaxation.
  - This leads to crack initiation at this location at an early stage and subsequent LCF cracking along letter box.
- Applying a TBC around the cooling holes at the tip can approximately halve the creep strain at this location, which is still very close to the amount in which creep damage occurs.
- A TBC system in combination with Sulzer EEQ111 base material results in a maximum local creep strain of 0,8%



Finite element analysis

LCF at LE cooling holes

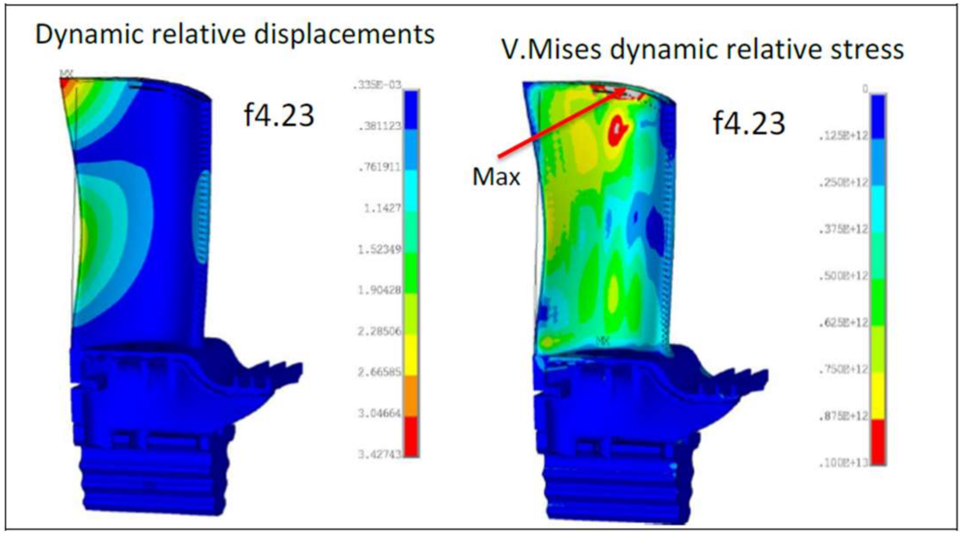
- The OEM blade with Inconel 738 base material and cooling holes non-TBC coated has a design life of approximately 800 starts .
- After approximately 500 starts LCF cracking is already observed.
- According FEM calculations, Sulzer design using EEQ111 base material and full coverage of TBC coating, cracking is not expected before >10.000 starts

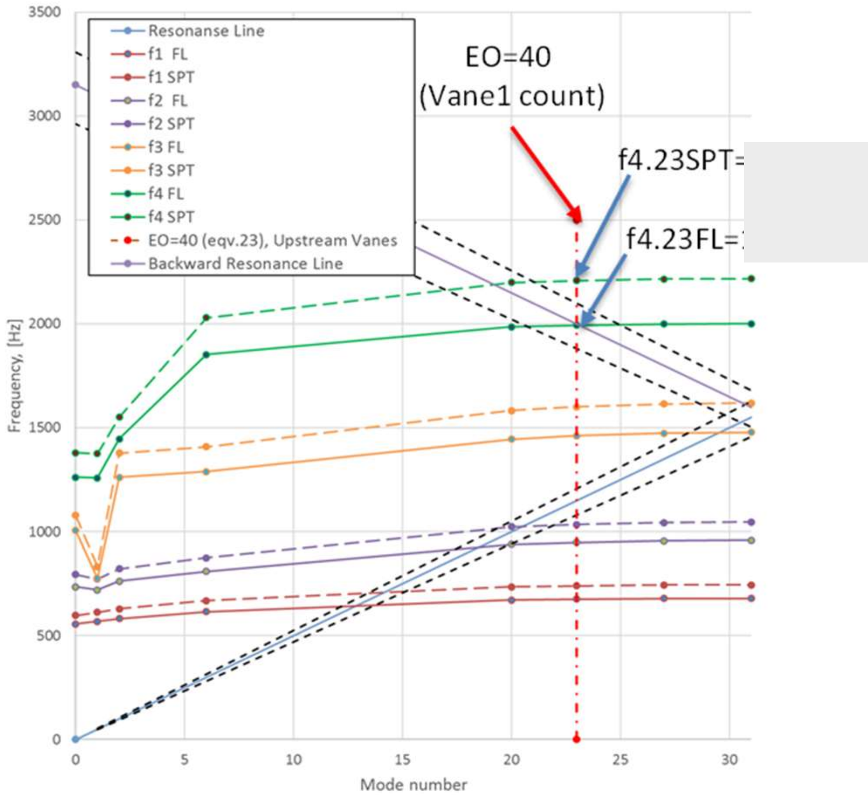


Finite element analysis

HCF cracking at TE

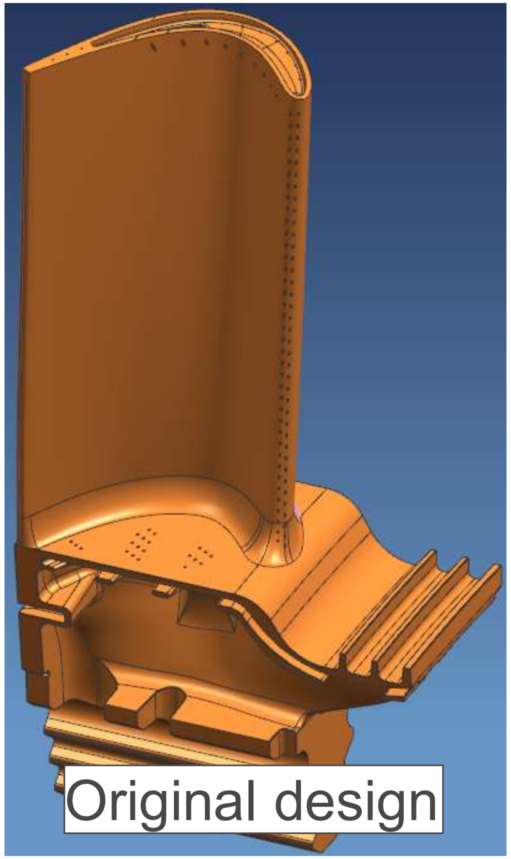
- In the OEM design of the blade, the 4th nodal mode is critical and its natural frequency can be exited during operation.

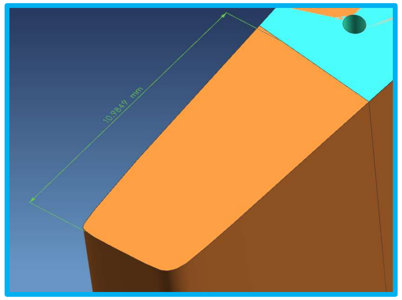




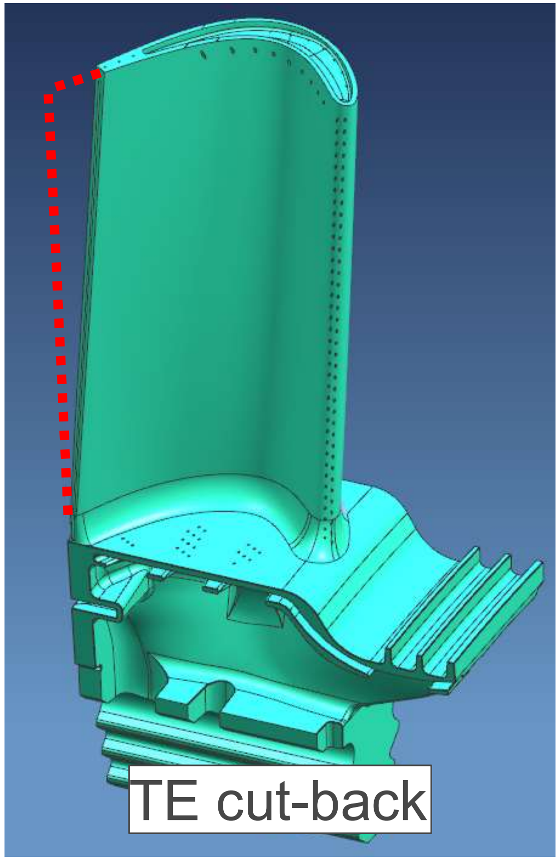
Finite element analysis

HCF cracking at TE





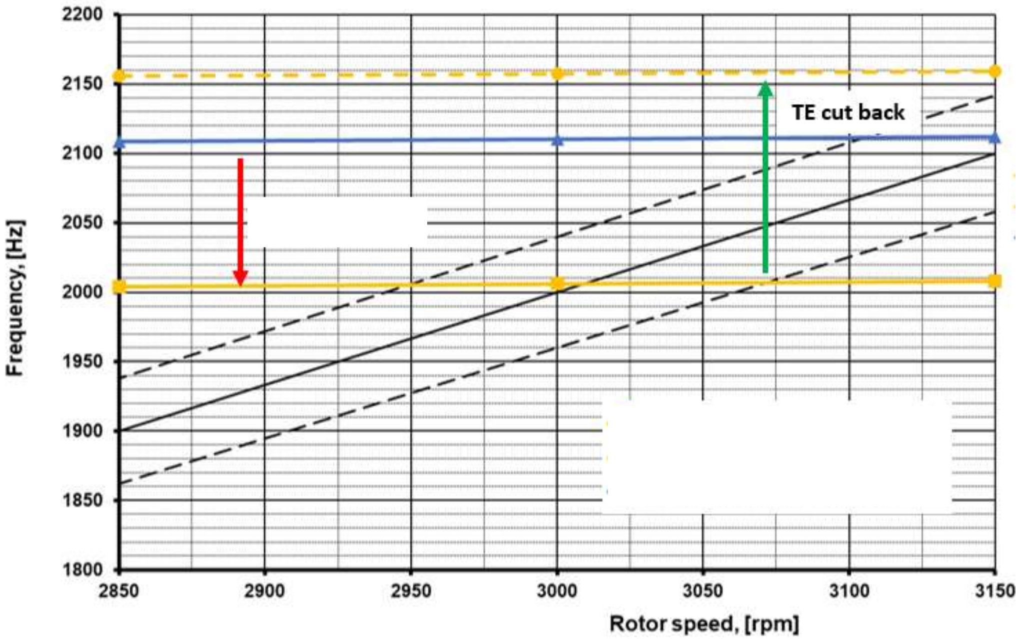
Sulzer upgrade modification



Finite element analysis

HCF cracking at TE

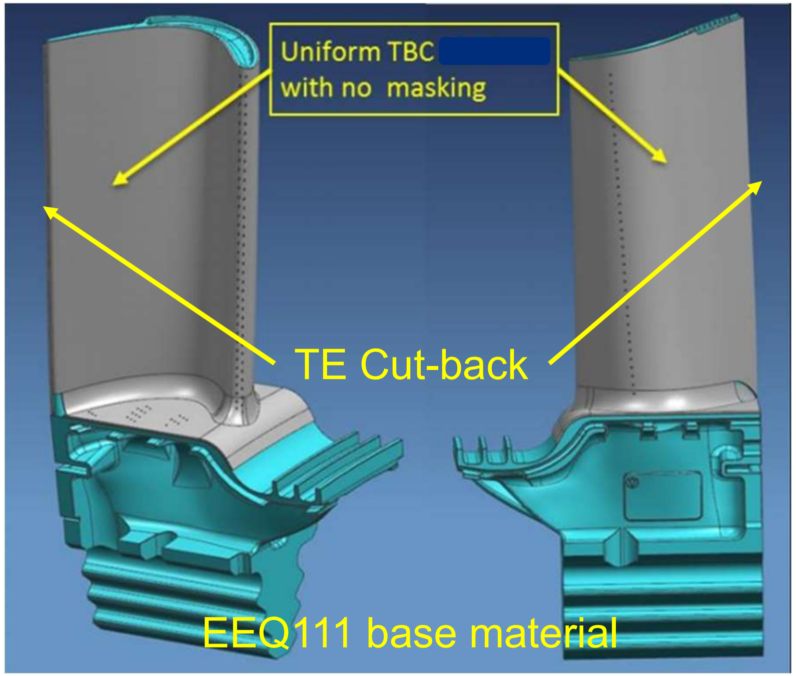
- For TE cut-back design, the f4.23 frequency is increased and tuned out of resonance.



TBO extension

C.) Upgraded new part required

- EEQ111 instead of Inconel 738 as base material
  - Reduction of local creep strain at 7th cooling hole below 1%, resulting in no crack initiation.
- Full coverage of TBC
  - In combination with EEQ111 base material, LCF cracking at LE cooling holes is not life limiting anymore.
- Cut-back of trailing edge
  - Tunes 4th nodal mode out of resonance and eliminates HCF cracking at this location.



TBO extension

Conclusion

- Based on OEM information, component damage history, repair experience, mechanical and chemical properties and simulations, an upgrade strategy can be developed for turbine components.
- As a result of the analysis:
  - Certain components can be used for extended interval without upgrade;
  - Several components can be upgraded during repair;
  - Occasionally components must be replaced by an upgraded version
    - Sulzer, has developed a upgraded parts for replacement
      - e.g. Alstom GT13E2 MXL first stage blade