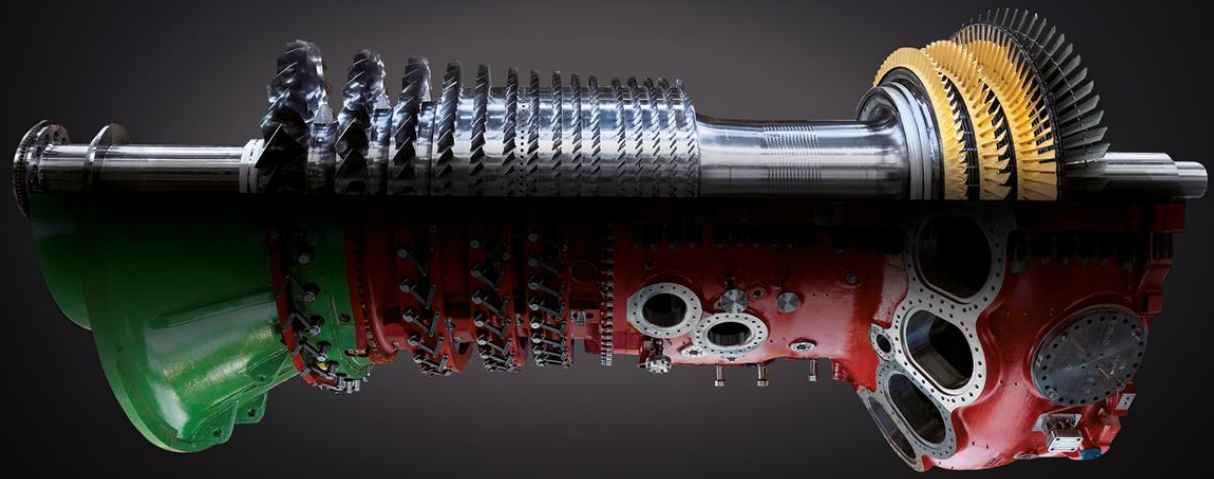
ITALIAN ENERGY

BRIGHTER FUTURE



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Ansaldo Energia's gas turbine rotor lifetime assessment and methodologies

D.Ugel, S.Ivkovic, T.Winge, L.Bordo

ETN Workshop, Stuttgart, 8-10 October 2024

Main Topics and Agenda

- Motivation
- Rotor architectures in AE Products Portfolio
- **Product Development Phase = general for rotor type/rating**
  - Standard Mechanical Integrity Assessments Workflow
  - WEM and Thermal transient effects
  - Effect of material degradation on lifetime
  - Rotor Lifetime Monitoring (RLM)
- **LifeTime Assessment/Extension (LTA/LTE) = specific for unit**
  - Operational data assessment
  - Condition assessment based on RLM
  - Material characterization
  - Evaluations, Decisions, Maintenance
  - Examples
- Summary

Motivation

Energy market forecasts highlight the need for LT extension and peaking operational regime

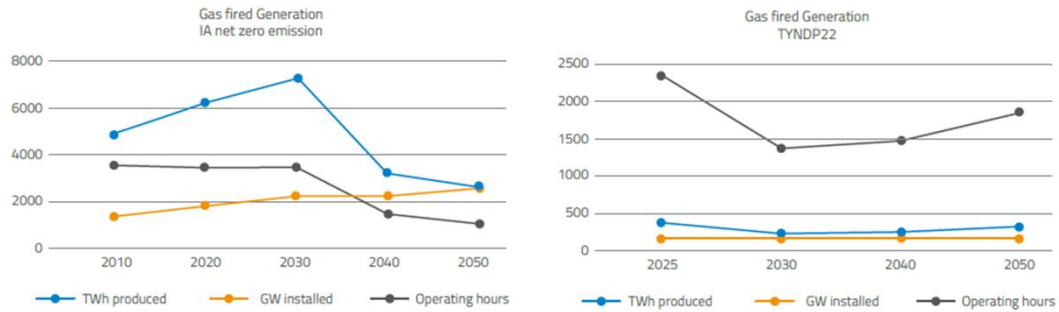


Figure 6: Gas fired generation worldwide (graphic at the left) and EU27 (graphic at the right)

	Cycles per annum	Period of operation
Base load	40	1980-2020
Two-shift	400	2020-2040
Peaking	800	2040-2050

Table 1: Start/stop assumptions for the several operational regimes and date of installation

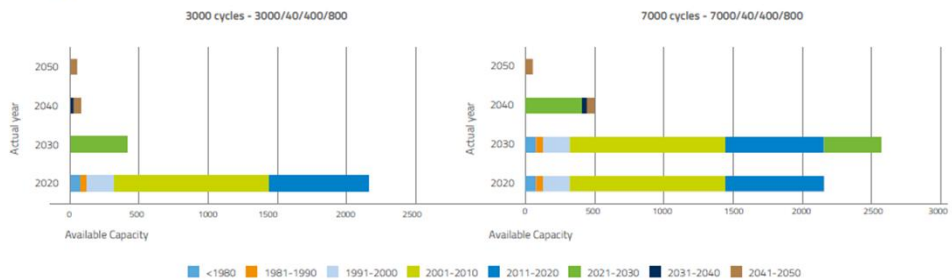
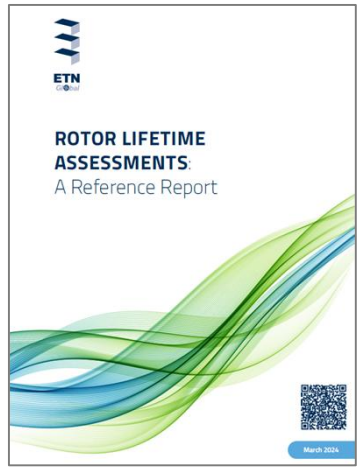


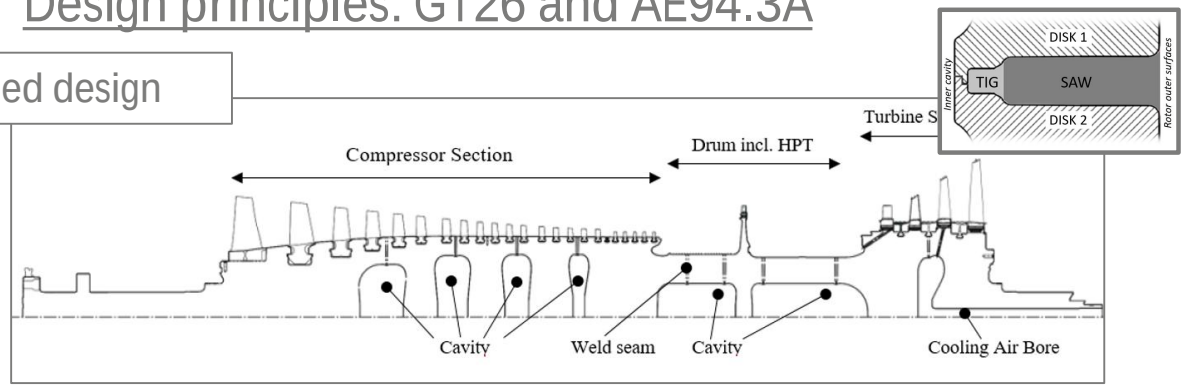
Figure 9: Available global GT capacity for a rotor life of 3000 cycles and 7000 cycles



Rotor architectures in AE Products Portfolio

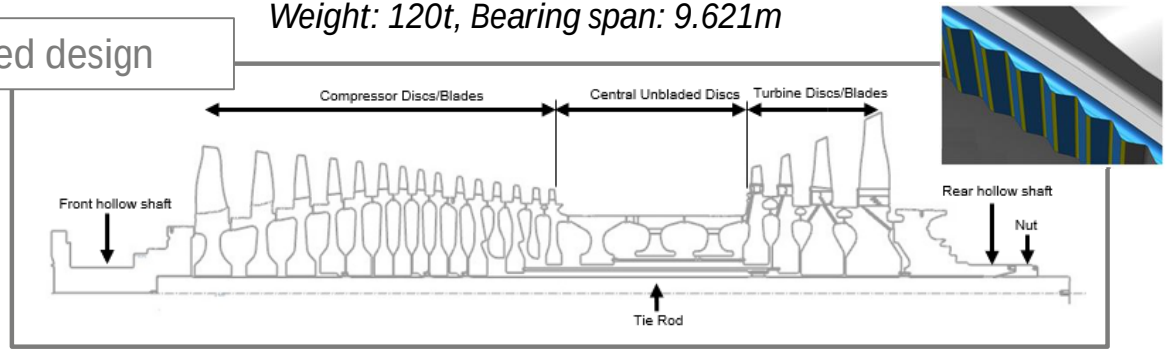
Design principles: GT26 and AE94.3A

Welded design



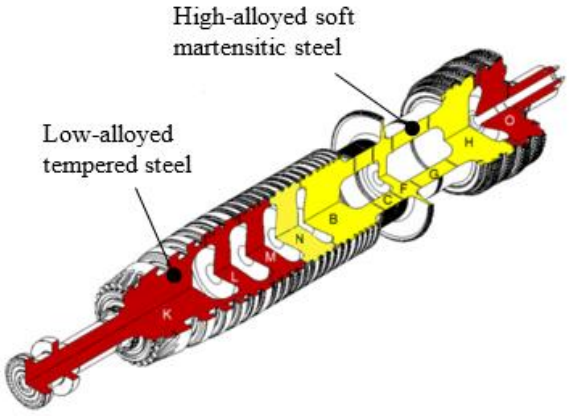
Weight: 120t, Bearing span: 9.621m

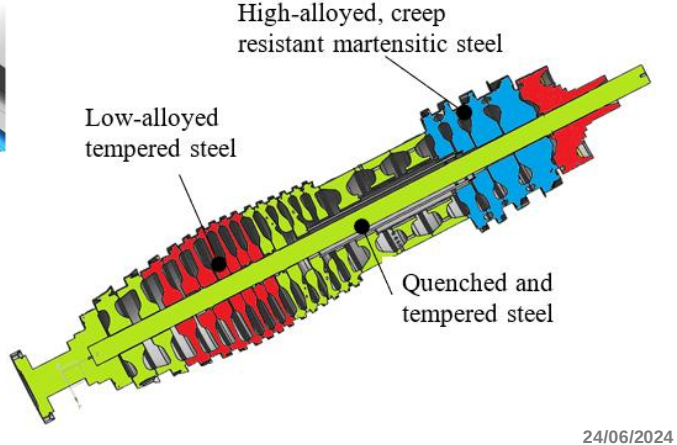
Bolted design



Weight: 80t, Bearing span: 8.446m

Source:
ASME
GT2024-128686

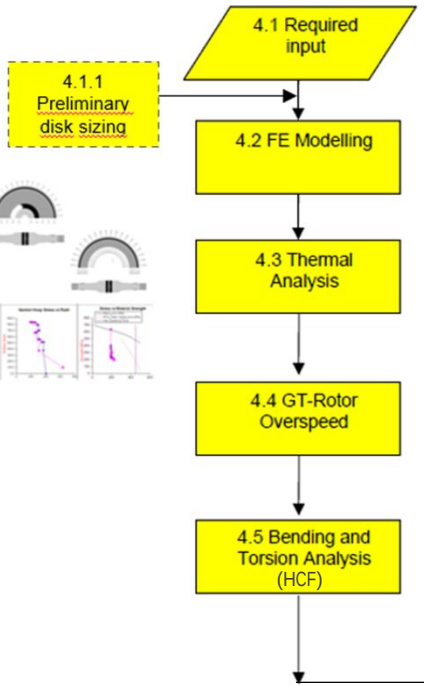


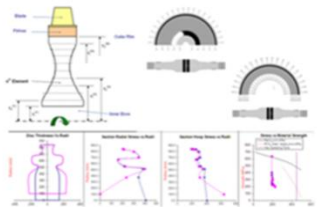


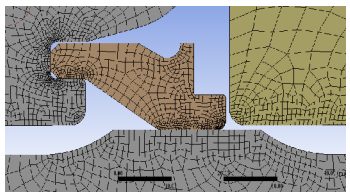
Product Development/Upgrade Phase

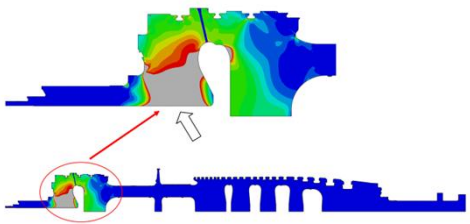
MI Standard Assessment Workflow

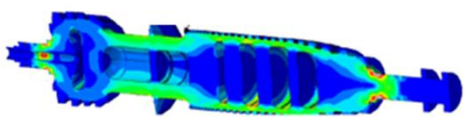
- Main Damage Mechanisms

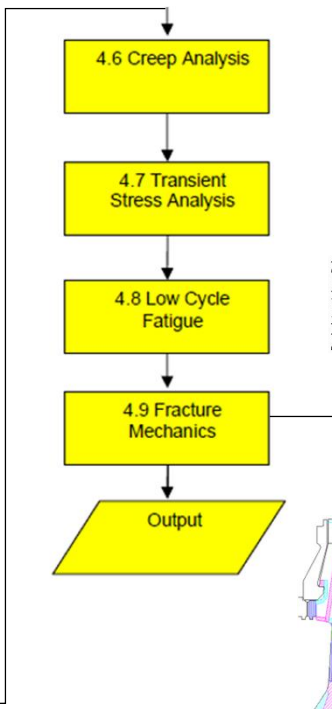


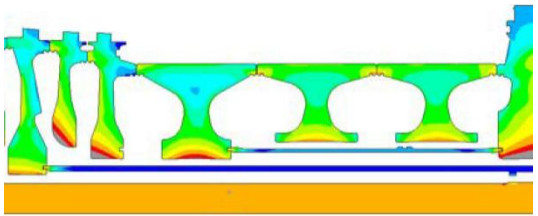


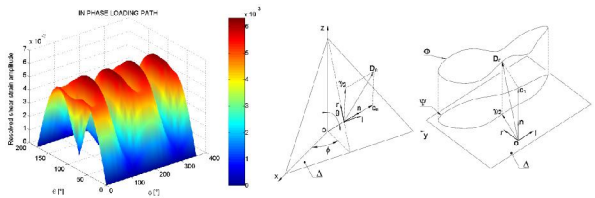


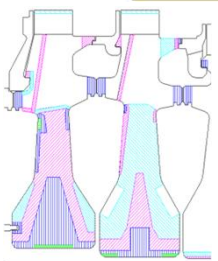


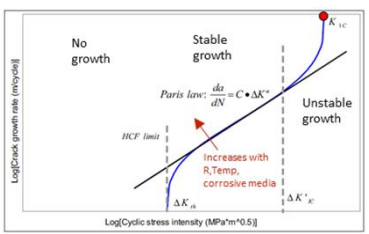










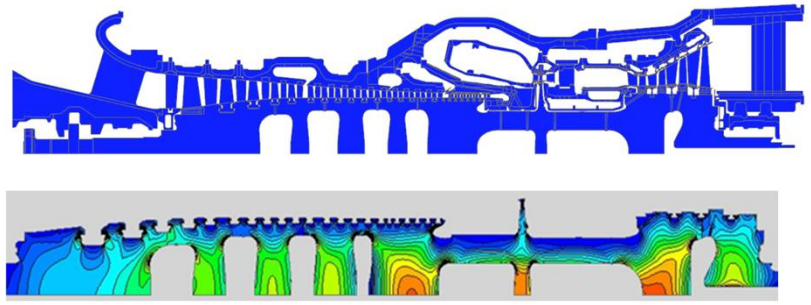


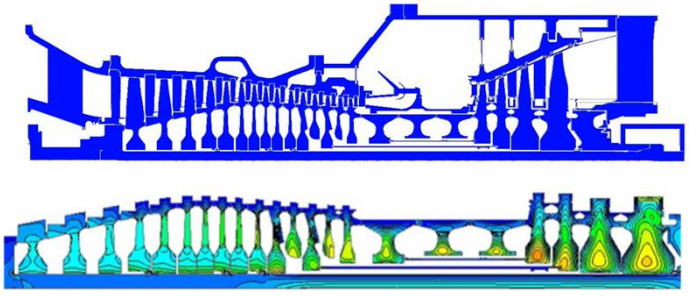
Manufacturing process is also considered.

Product Development/Upgrade Phase

Thermo-Mechanical Whole Engine Modeling (WEM)

- Parametric transient thermo-mechanical coupled models
- Can be used for any engine mission cycle
- Are maintained for all engine type @ Ansaldo
- Key for Clearance & Lifetime predictions





Temperature *@ transient cold start*

Eq. Stress *@ BL reached*

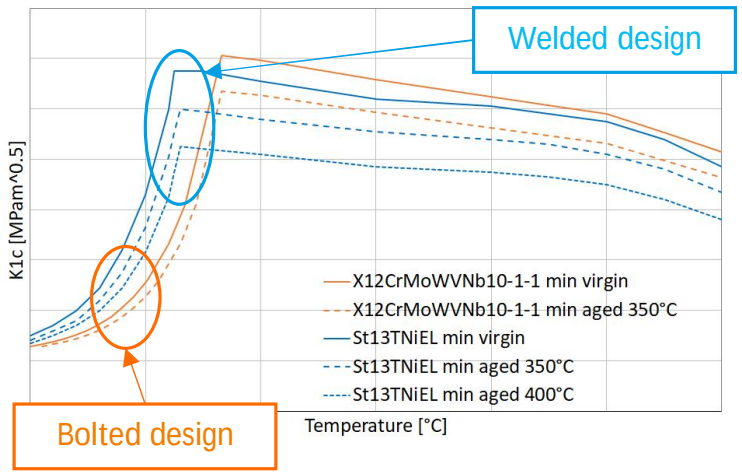
- Timelines different between rotor and stator è major driver for clearance assessment
- Different heating and cooling of the inner relative to outer metal è major driver for lifetime assessment

Source:
ASME
GT2024-128686

Product Development/Upgrade Phase

Effect of material degradation on lifetime

- Besides initiation of new defects or propagation of existing defects, material and surface degradation can be expected:
  - Corrosion (surface degradation due to environment)
  - Fretting (relative movements of contact surfaces)
  - Softening (reduction of strength due to creep and cyclic loading)
  - Aging/Embrittlement (reduction of toughness for long term exposure at high temperature)



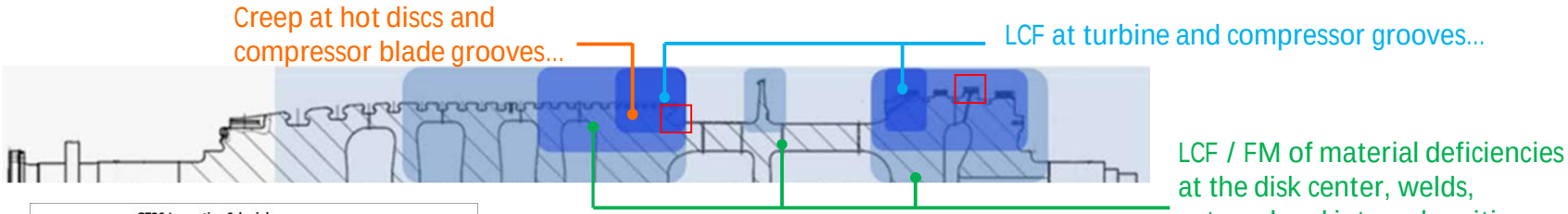
- Welded design working mostly on upper shelf of KIC curve
- Bolted design working on lower shelf of KIC curve

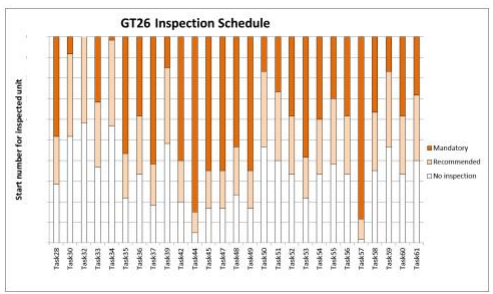
Source:
ASME
GT2024-128686

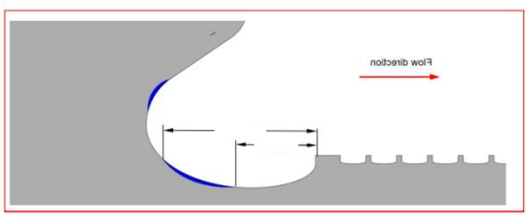
Product Development/Upgrade Phase

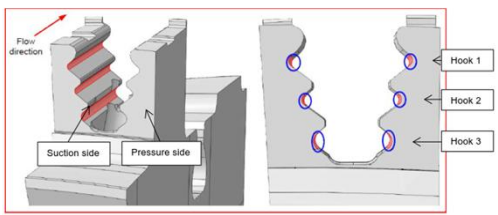
Rotor Lifetime Monitoring (RLM)

- The monitoring program is defined for each engine family separately, mostly performed during major outages, scope increasing with the number of starts or operating hours
- Mechanical Integrity (incl. field experience) à Identification of life limiting components/locations à definition of inspection tasks, schedule, procedures and acceptance criteria (size, orientation)







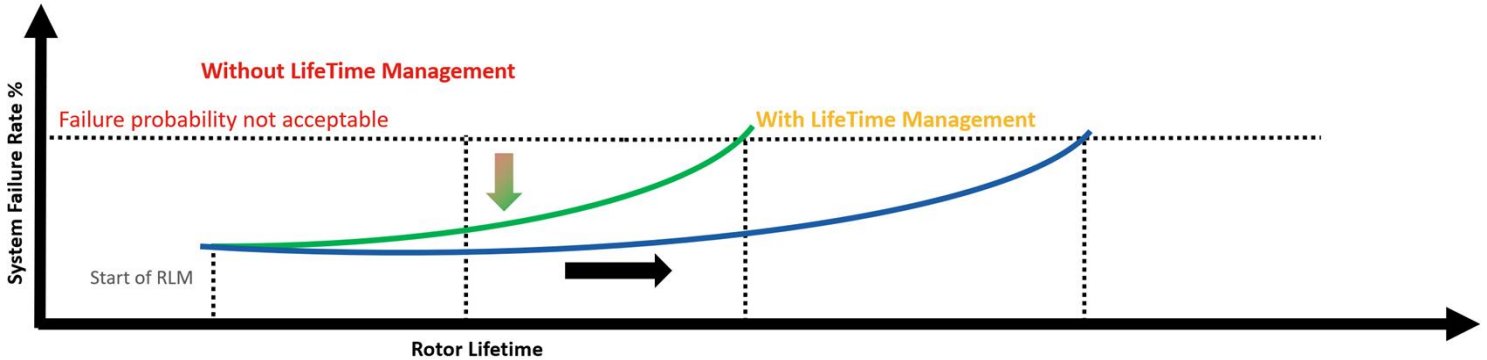


- Field inspection techniques and location specific tools development in collabrations with Service Assessment/NDT specialists

LifeTime Assessment/Extension (LTA/LTE)

Introduction

- Specific lifetime based on monitoring results and available repair measures



Minimum Expected Lifetime
General for fleet
Requires visual inspections only

General for a rotor fleet/design

Expected Lifetime
General for fleet
Requires Rotor Monitoring
& condition-based repairs

General with RLM based on ODC readings

Specific Lifetime
Component specific
Requires Rotor Monitoring
& condition-based repairs

Rotor-specific

LifeTime Assessment/Extension (LTA/LTE)

Procedure

Validated lifetime prediction capability with OEM knowhow essential for assessment of both architectures:

1. Operational data assessments:
   - kOH vs Starts
   - Load ramp (MW/min)
   - Thermal status
   - Base- vs Part-load

→

2. Condition Assessment based on RLM:
   - Structural
   - Dimensional
   - Environmental

→

3. Material Condition Assessment (characterization):
   - Disk specific virgin properties
   - Disk specific aged properties (Lab tests based on extracted samples)

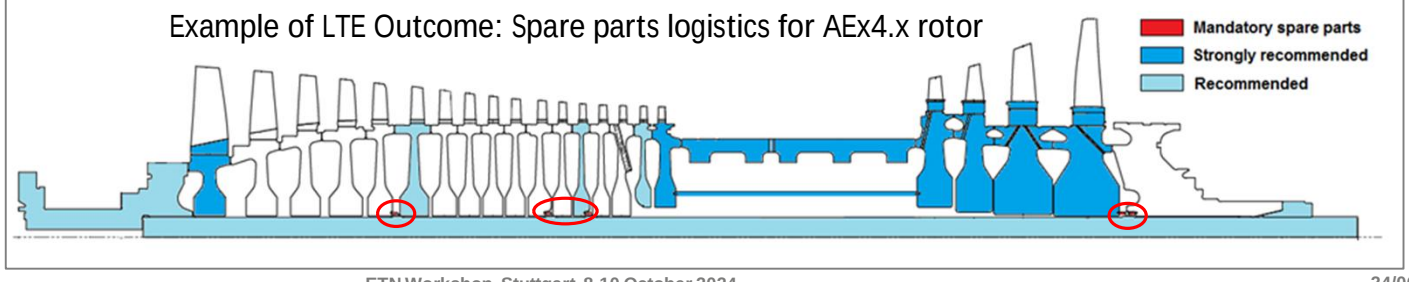
→

4. Evaluations: life limiting components/locations for fleet or unit specific Lifetime assessment based on all above

→

5. Decisions: maintanance (rework, replacements…), future operation (operation concept BLSSS, peaker, mixed…) and monitoring (next inspection interval and scope)

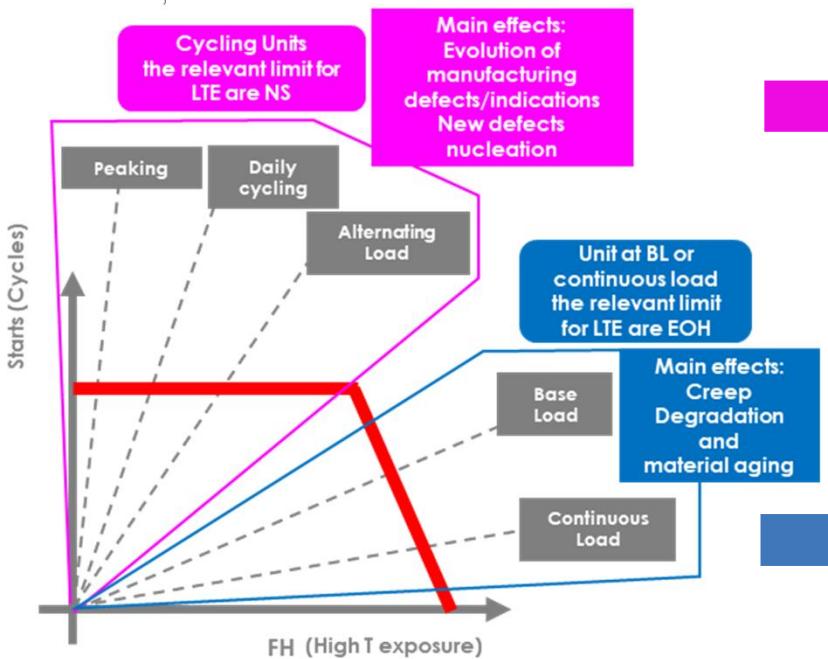
Example of LTE Outcome: Spare parts logistics for AEx4.x rotor

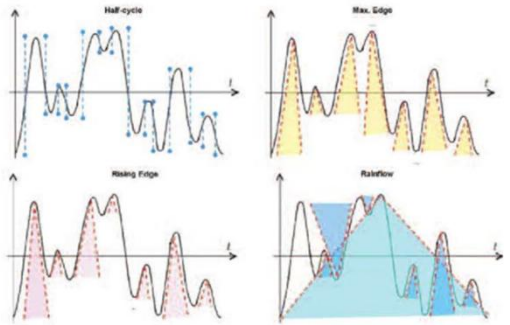


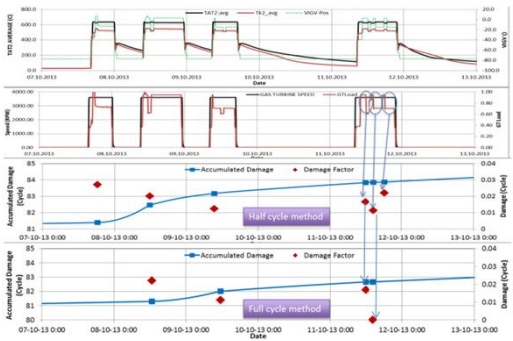
LifeTime Assessment/Extension (LTA/LTE)

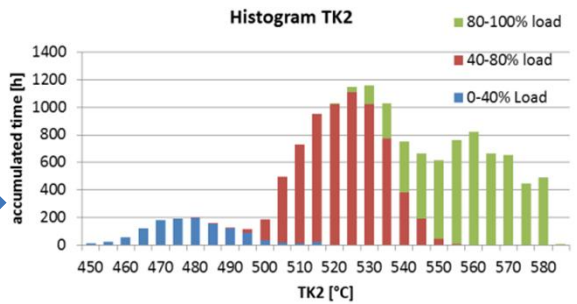
Operational data assessment

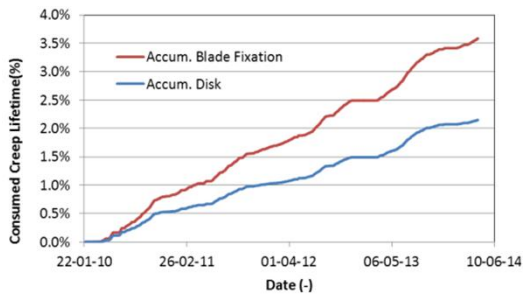
- Effective operational regime: Starts vs kOH, Warm or Cold restarts, Ambient (°C), Load ramps (MW/min), Tk2 (°C)…









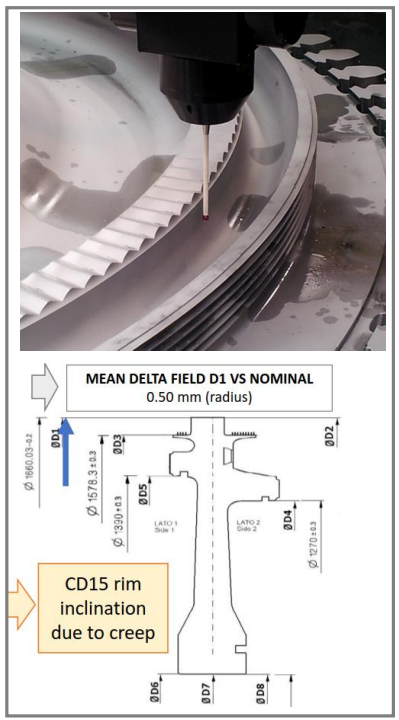


LifeTime Assessment/Extension (LTA/LTE)

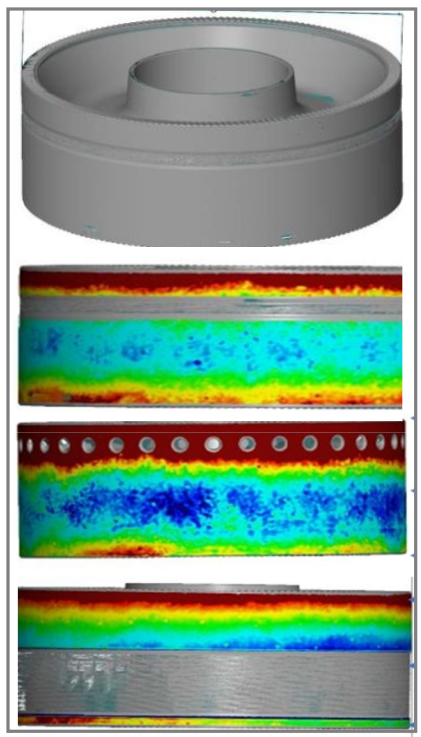
Condition assessment

- Dimensional (Geometrical): CMM, Laser, PI tape

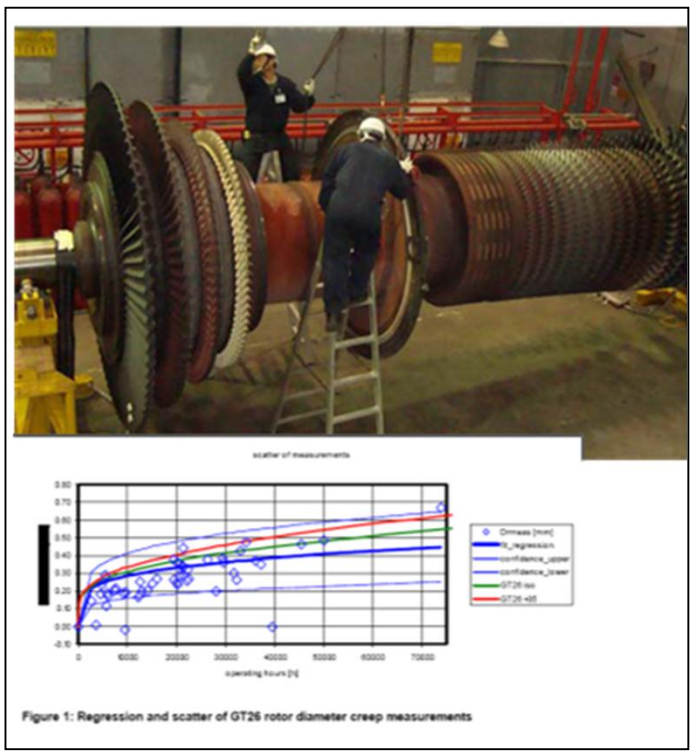
CMM measurement



Laser measurement



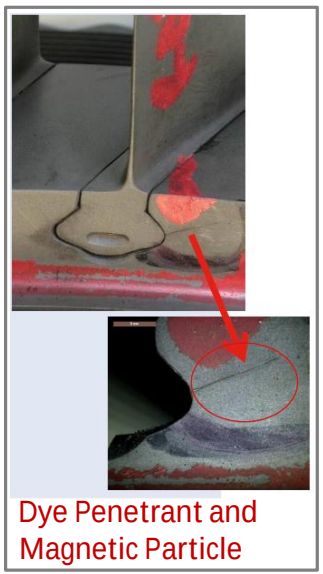
PI tape diameter measurement

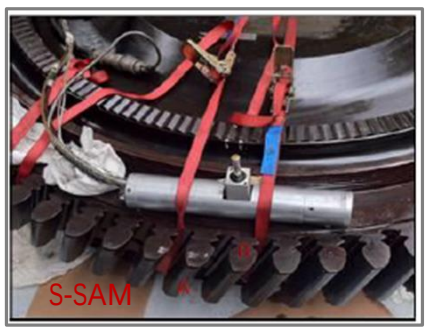


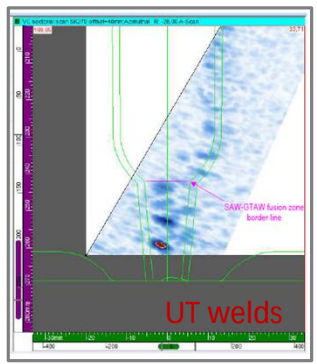
LifeTime Assessment/Extension (LTA/LTE)

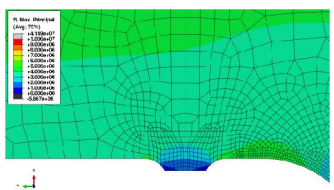
Condition assessment

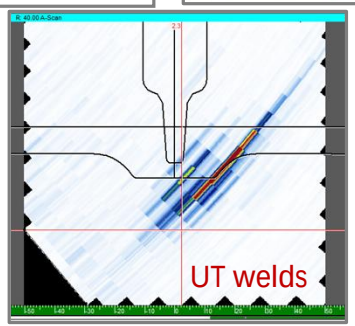
- Structural (external and internal): Visual (incl. Boroscope), Magnetic Penetrant, Dye/Fluorescent penetrant, Eddy Current, S-SAM (Surface Sampling), Ultrasonic (incl. Phased Array).







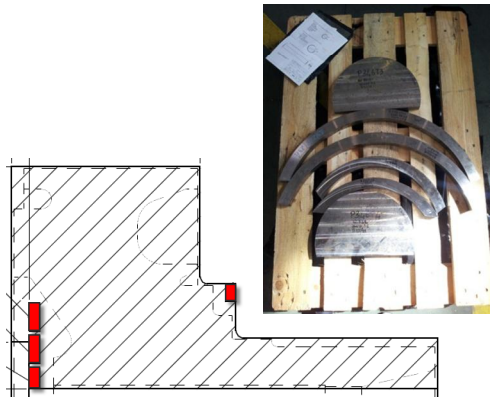




LifeTime Assessment/Extension (LTA/LTE)

Material characterization

- Review delivery documentation for disk specific virgin condition
- On-site or laboratory metallographic and mechanical tests
  - on stored samples for properties not included in delivery documentation
  - on S-SAM for various testing including SPT (Small Punch Tests) extracted from components/locations of interest during outages



LifeTime Assessment/Extension (LTA/LTE)

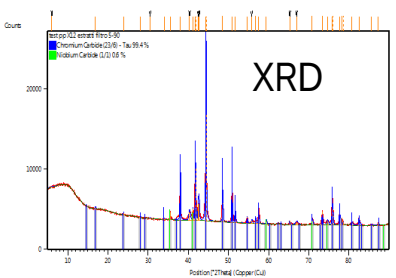
Material characterization

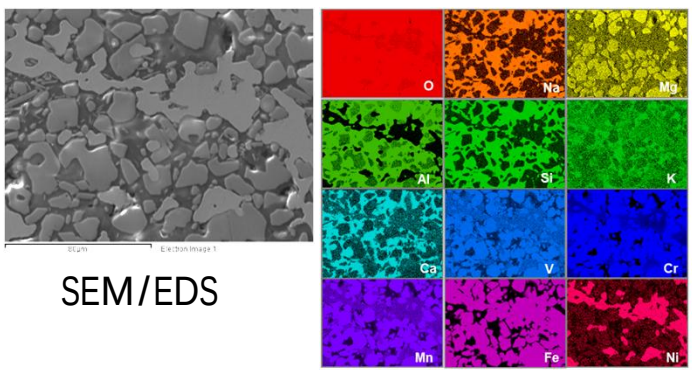
- Surface-Sampling (S-SAM) à Optical, SEM/EDS, XRD…
  - Chemical analyses (composition and impurity content embrittlement)

$$X = (10P + 5Sb + 4Sn + As) * 10000/100$$

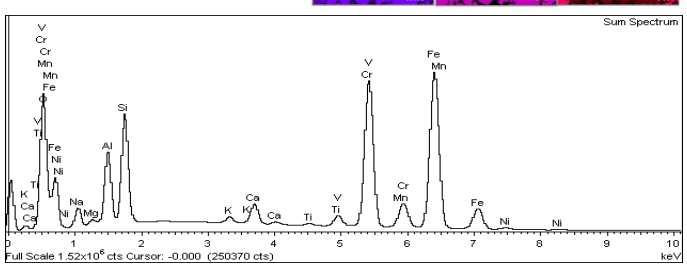
$$J = (P + Sn) \cdot (Mn + Si) \cdot 10^4$$

  - Microstructural analyses à possible degradation or alteration and creep damage, grain size, micrography (type and morphology of the present carbides)
  - Macro and micro hardness on metallographic specimens à conversion of the maximum tensile strength





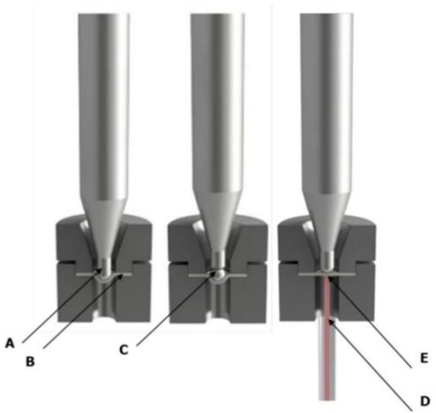
SEM/EDS



LifeTime Assessment/Extension (LTA/LTE)

Material characterization

- Surface-Sampling (S-SAM) à Small Punch Test
  - Tensile and Creep
  - Fracture toughness and FATT50 estimation based on empirical internal correlations
  - Comparison to disk specific virgin condition/or to unloaded location



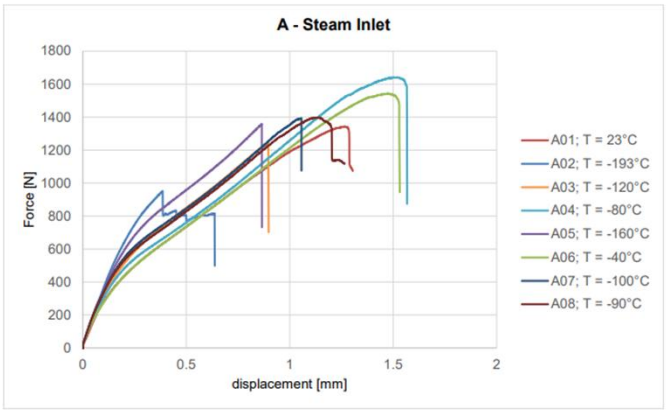


Figure 4.7 – Position A: HP inlet, SPT force/displacement curves

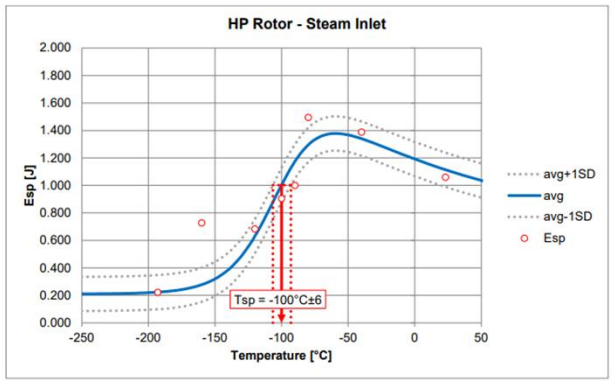
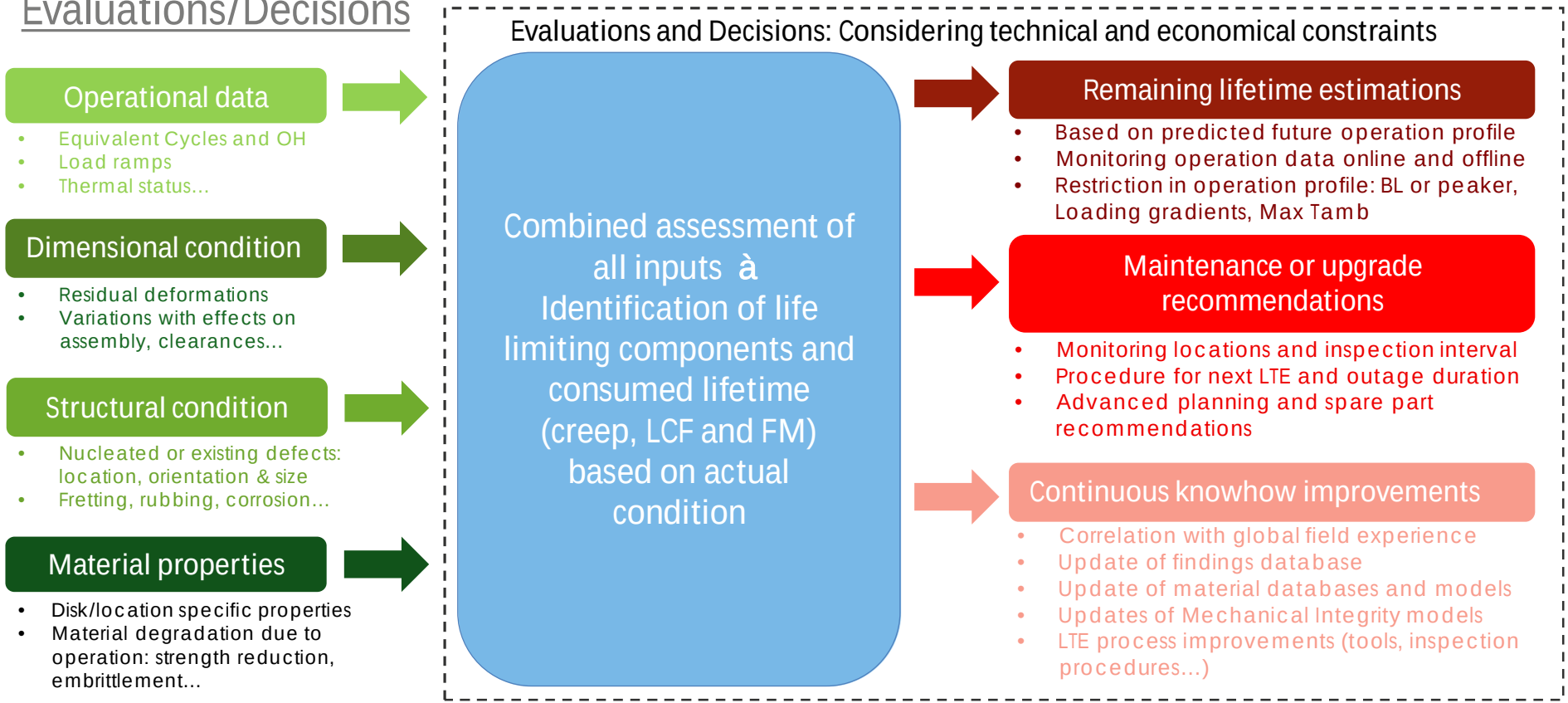


Figure 4.9 – Sample A, HP inlet. SPT energy transition curve

à Unit and location specific material embrittlement estimation

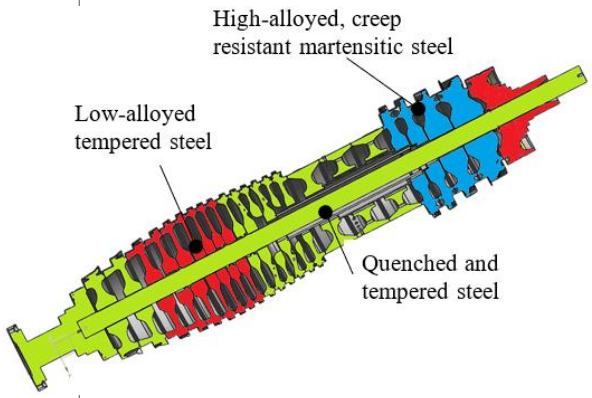
LifeTime Assessment/Extension (LTA/LTE)

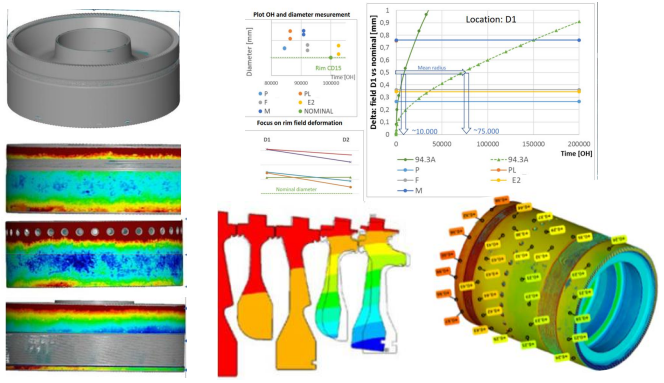
Evaluations/Decisions



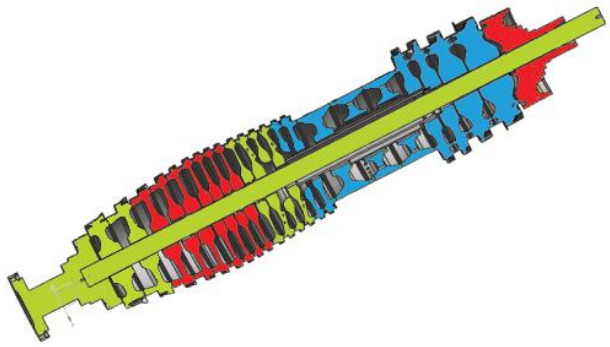
LifeTime Assessment/Extension (LTA/LTE)

AE94.3A





Unit specific → Upgrade of middle disks with new design and material

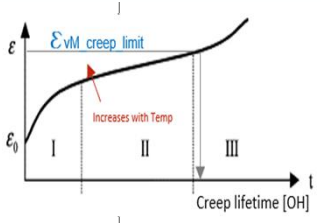


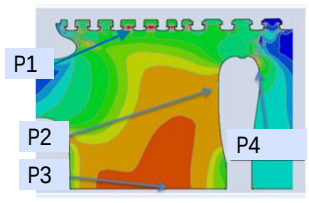
FEM MI 2D & 3D
General engine evaluation

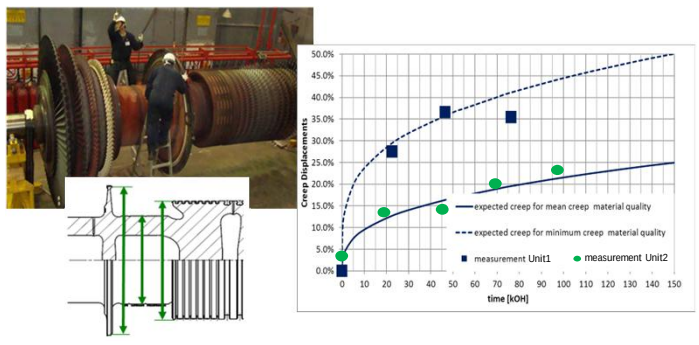
Inspection/Verification
Unit specific evaluation

LTE action

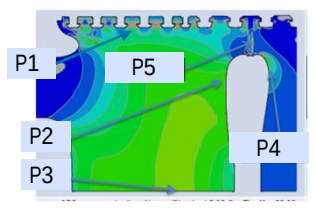
GT26







Unit specific operational and material data → LTE for 1C inspection interval



Summary

As OEM for E- F- H-Class engines Ansaldo Energia has the know-how and long time experience for rotor lifetime management and extension.

In this presentation we have specifically discussed the case of F-Class machines (GT26 and AE94.3A) and the corresponding rotor designs, namely welded and bolted.

It has been shown how the basic understanding derived from the development phase (engine type) allows a comfortable adaptation to the unit specific assessment.

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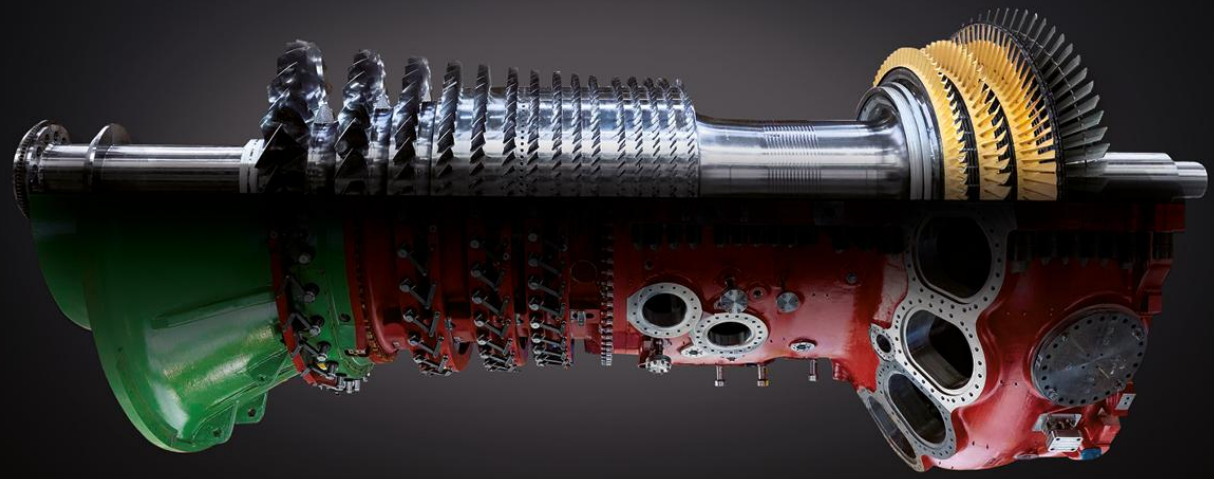

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