METS III
MIDDLE EAST TURBOMACHINERY SYMPOSIUM
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Blade Failure on an Axial Compressor Caused by Unexpected Operating at Choke

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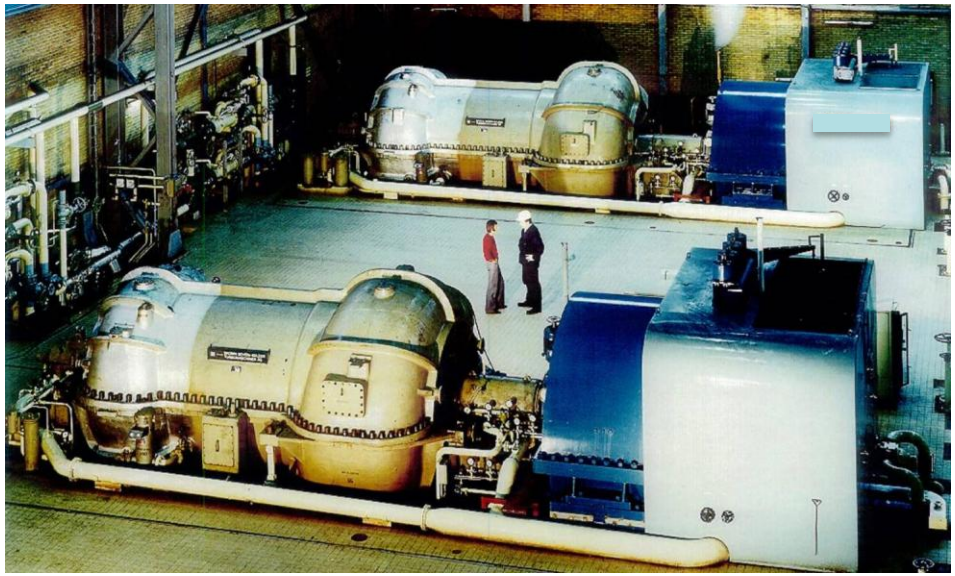
Contents

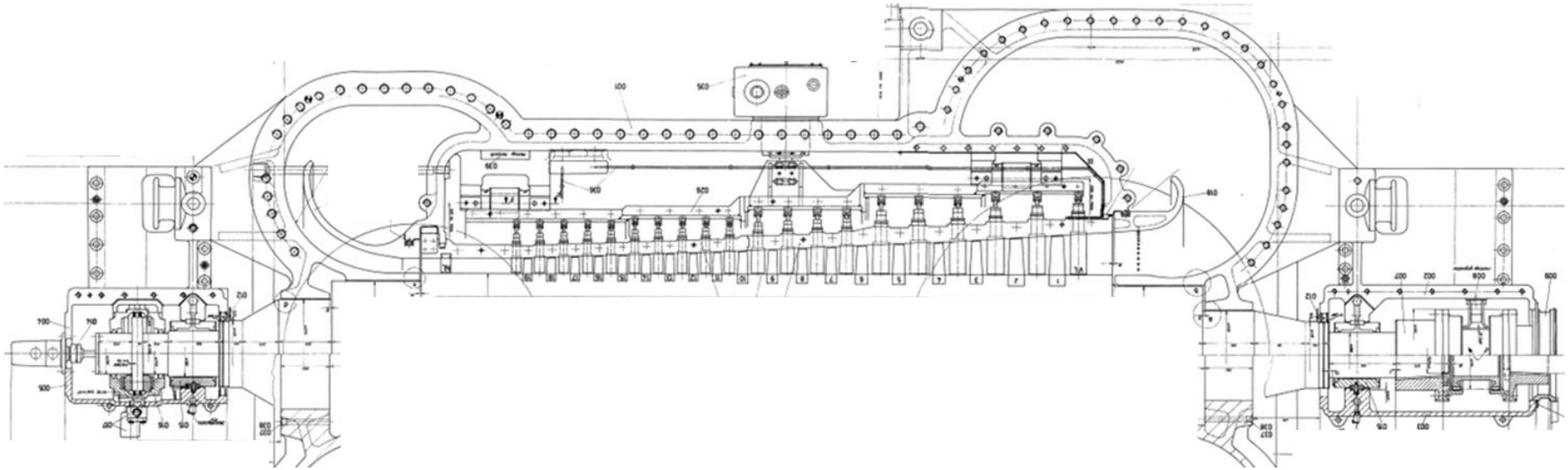
Background

- Two parallel trains consisting of axial air compressors driven by steam turbines
- Application: blast furnace
- In operation since more than forty years (trouble free)
- Recently : shutdown (planed) of one train with inspection of the compressor.
- After three months of operation break-down of this compressor.
- Blades damaged
- RCFA performed:
  - Reasons of the damage
  - Countermeasures



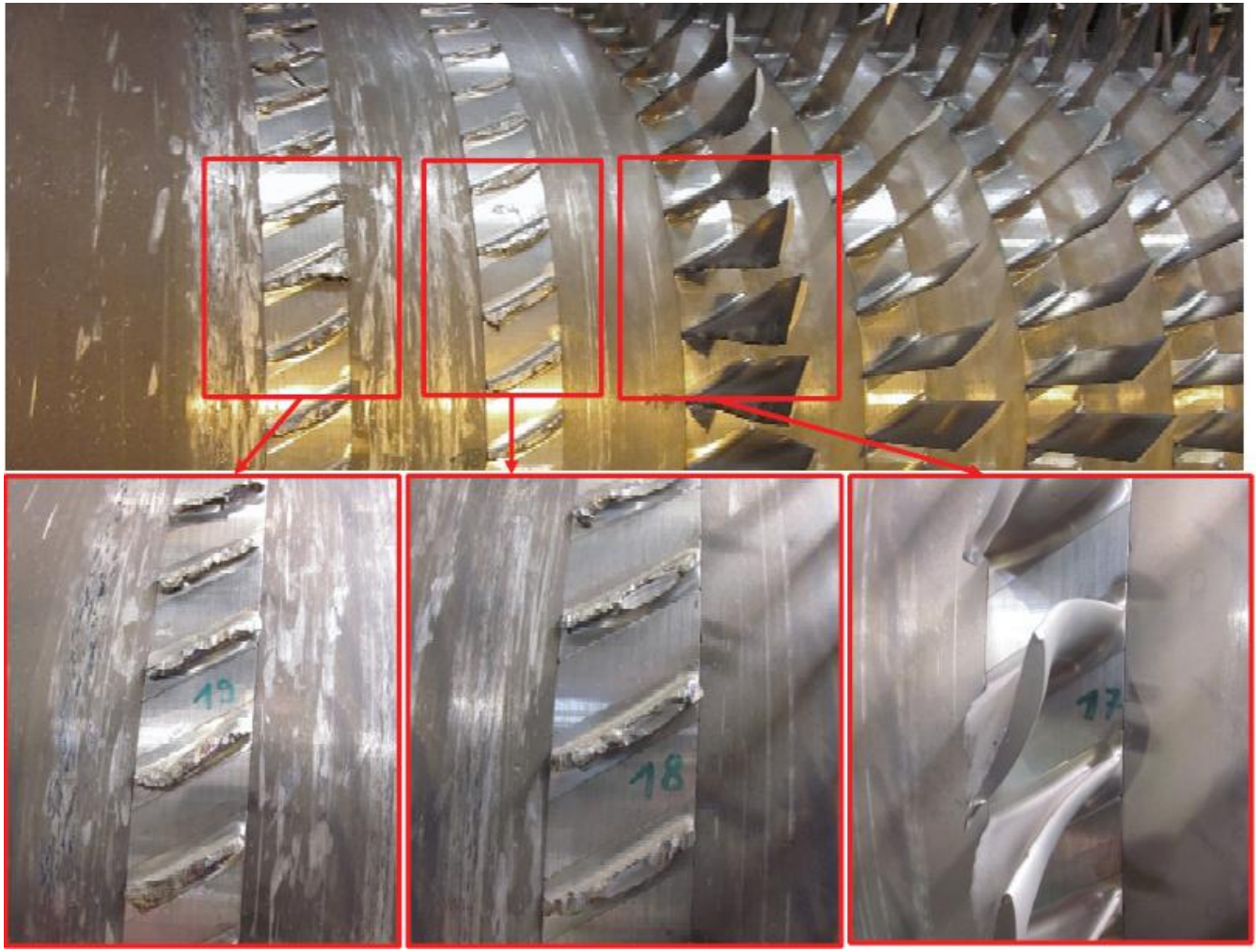
Description of the machine

- Axial compressor, 19 stages
  - gas handled : wet air
  - p_s= 1.0 bara
  - p_d= 5.5 bara
  - V = 450,000 Nm^3/h
  - P = 40.7 MW
  - $n_{operation}$ = 3,200 rpm
  - n_{min} = 2,856 rpm (89%)
  - n_{max} = 3,360 rpm (105%)



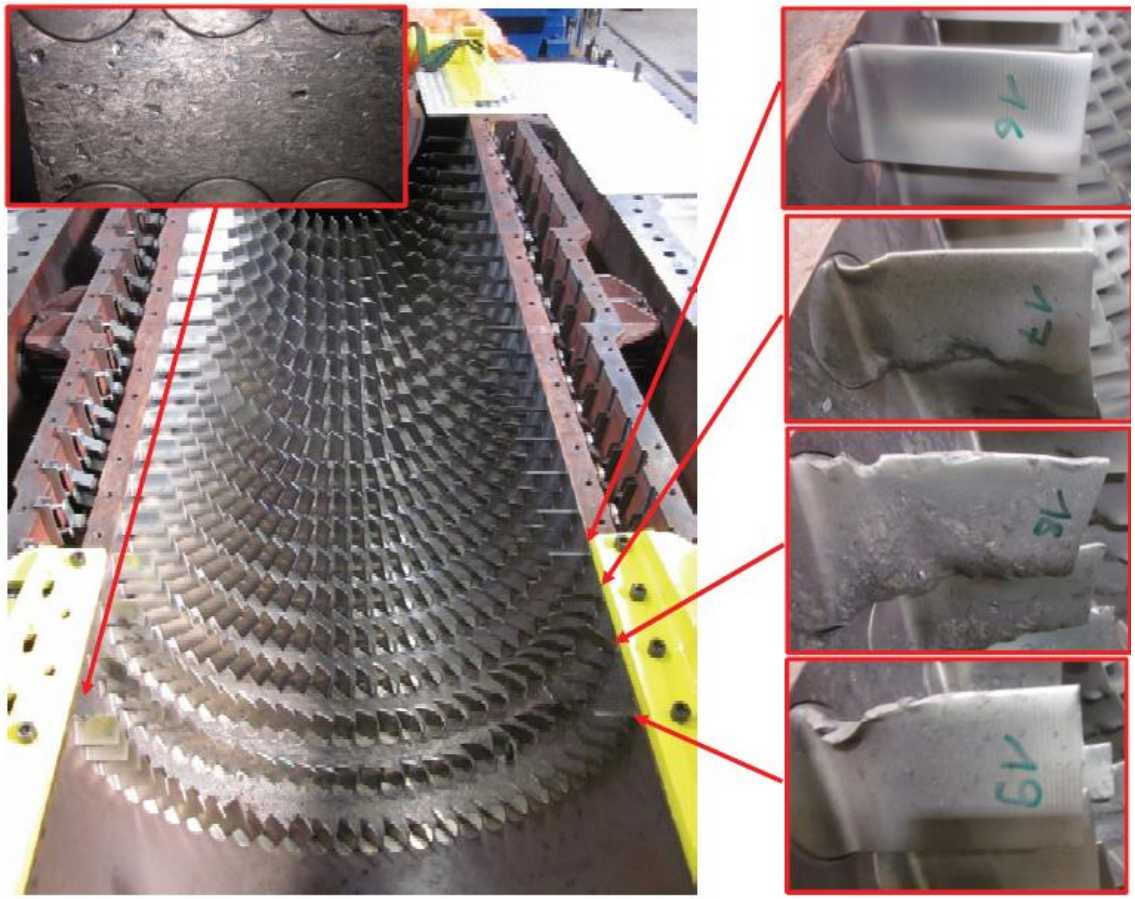
Findings

- Rotor: Major damages on stages 16 to 19



Findings

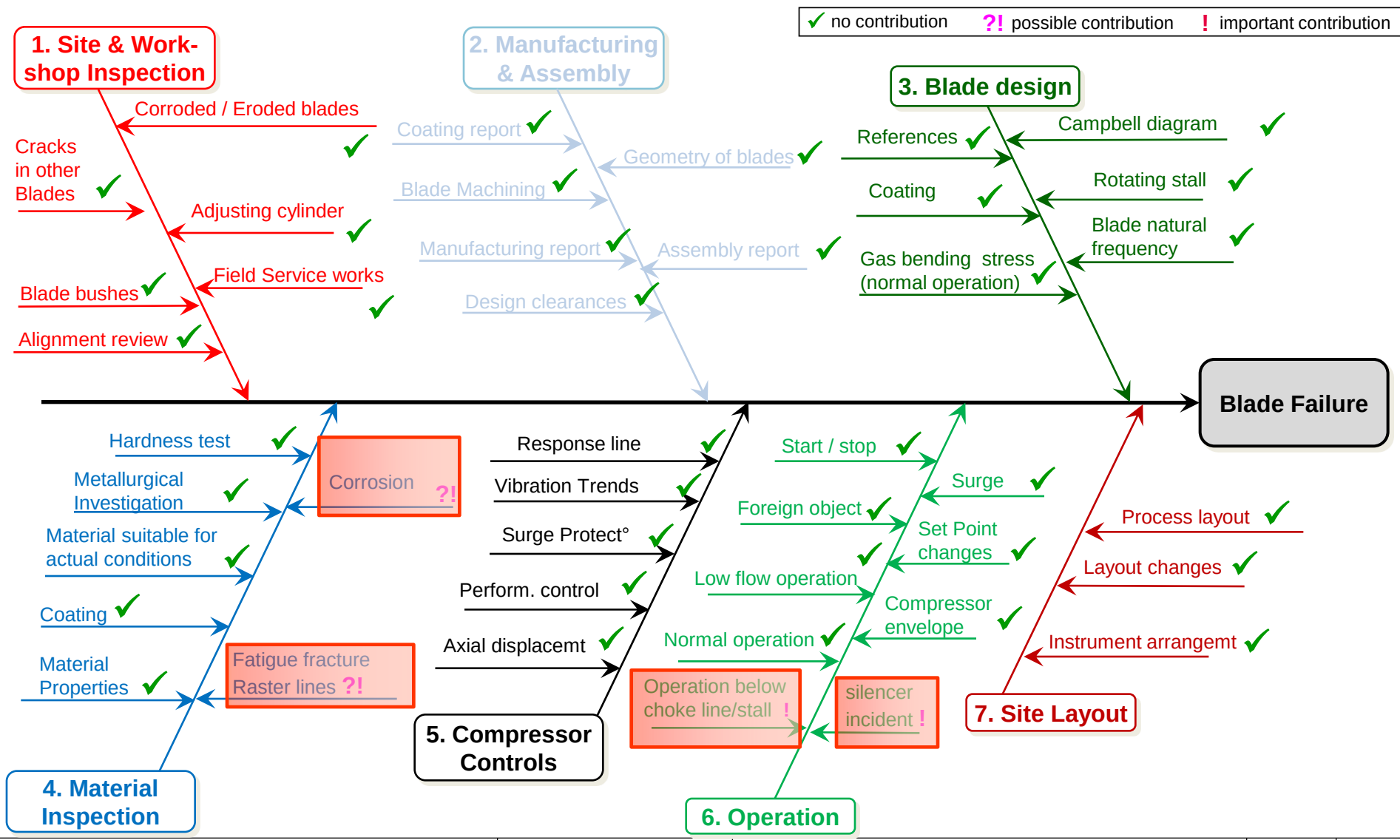
- Stator: Major damages on stages 16 to 19
  minor damages on blade carrier & lever system



Root Cause Failure Analysis

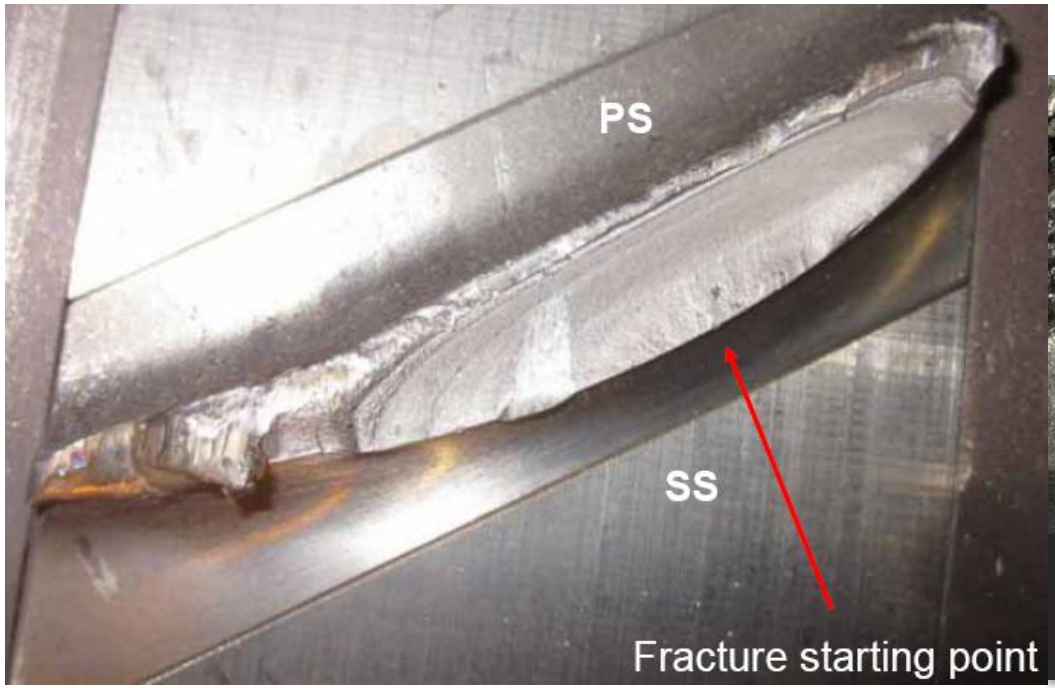
- In order to clear up the compressor break down cause, following investigations were performed:
  - on-site inspection
  - RCFA
    - laboratory analysis
    - timeline and operation data evaluations
    - aerodynamic investigations

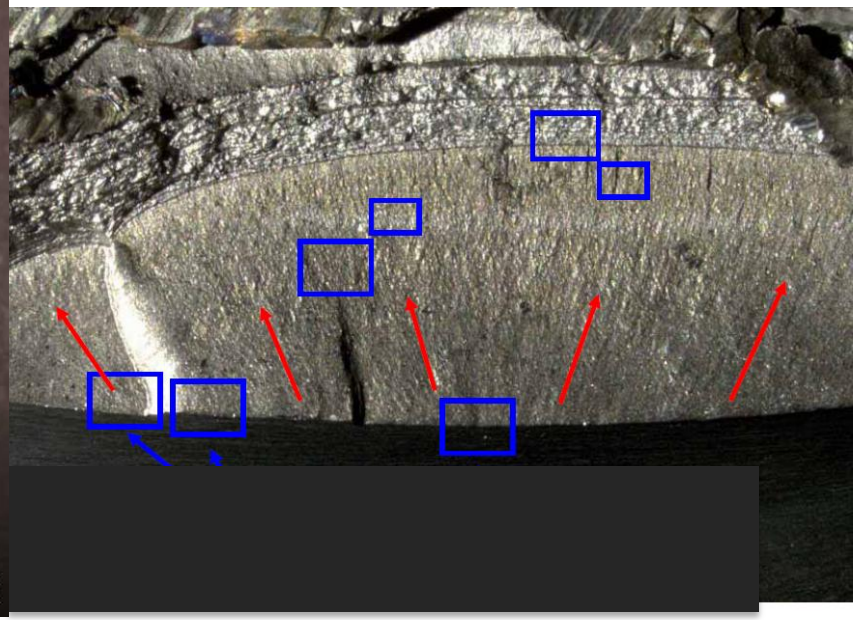
Root Cause Failure Analysis - Overview



RCFA – Laboratory analysis

- Blades failed/fractured in stage 18 & 19 (blades of stage 18 failed by material fatigue)
- Fracture initiation and propagation always on/from the back-side of the blades (transition area airfoil-blade root)





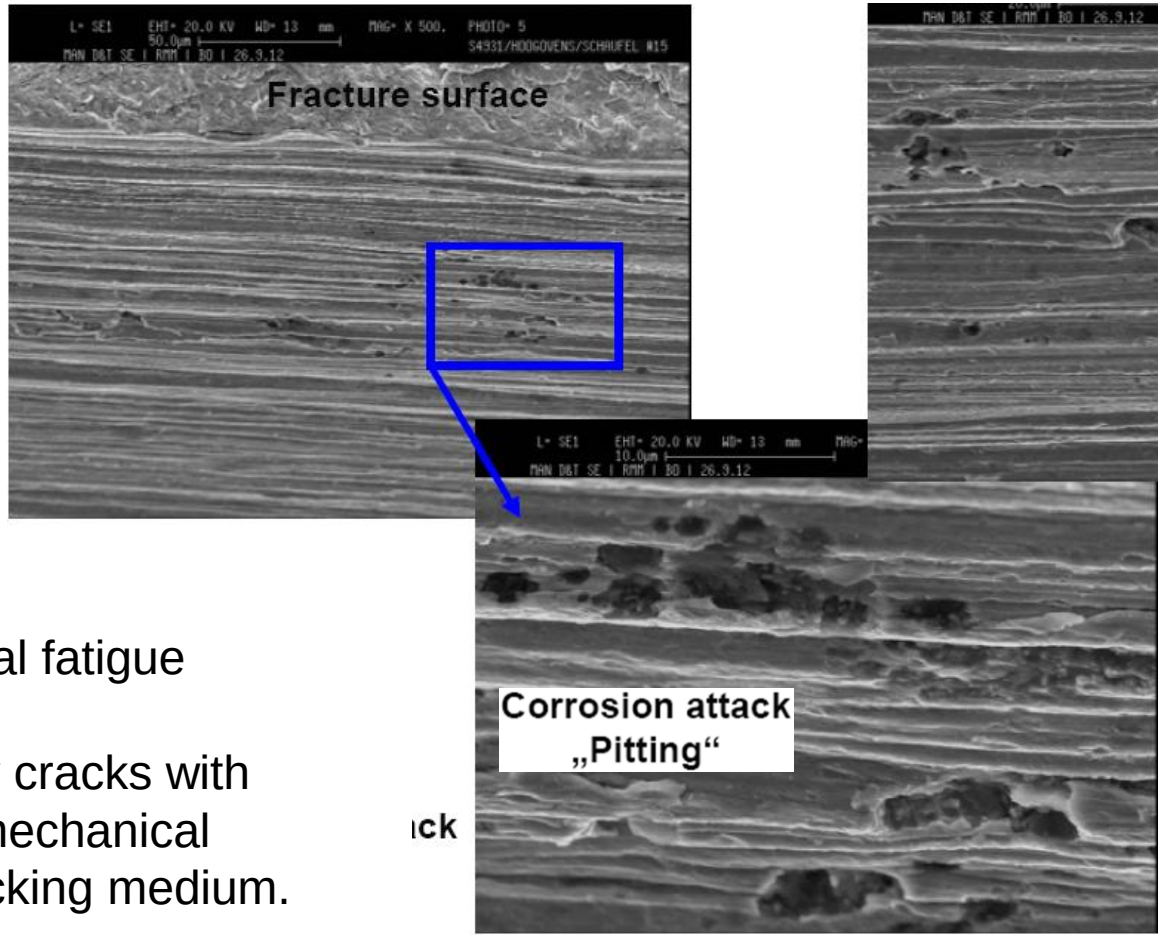
RCFA – Laboratory analysis

- Deposits with corrosive potential

➢ In all deposits, remarkable sulphur and chloride - enrichments in various concentrations.

➢ Deposits contain dilutable elements
→ corrosion of blade material (with moisture)

➢ Local corrosion reduces material fatigue resistance
→ corrosion fatigue caused by cracks with simultaneous influence of mechanical alternating load and of attacking medium.



RCFA – Timeline Evaluation, Operation Data Analysis

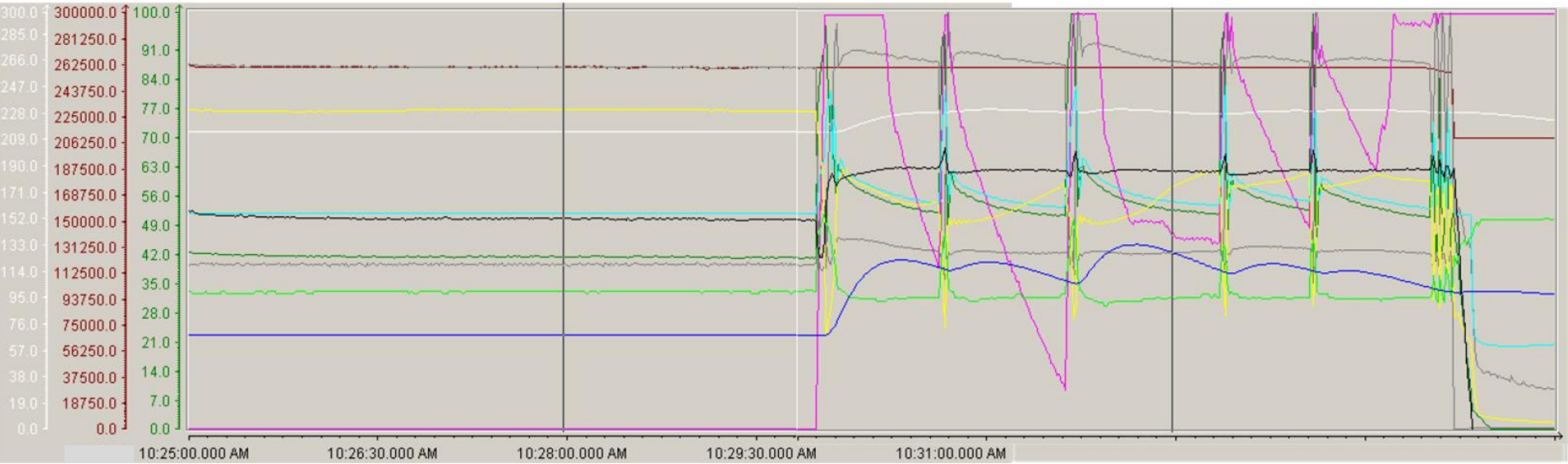
February: completion of compressor installation (new blading installed)

May : termination of commissioning

July 11th : silencer failure

July 31st : compressor breakdown

Operation data during compressor breakdown

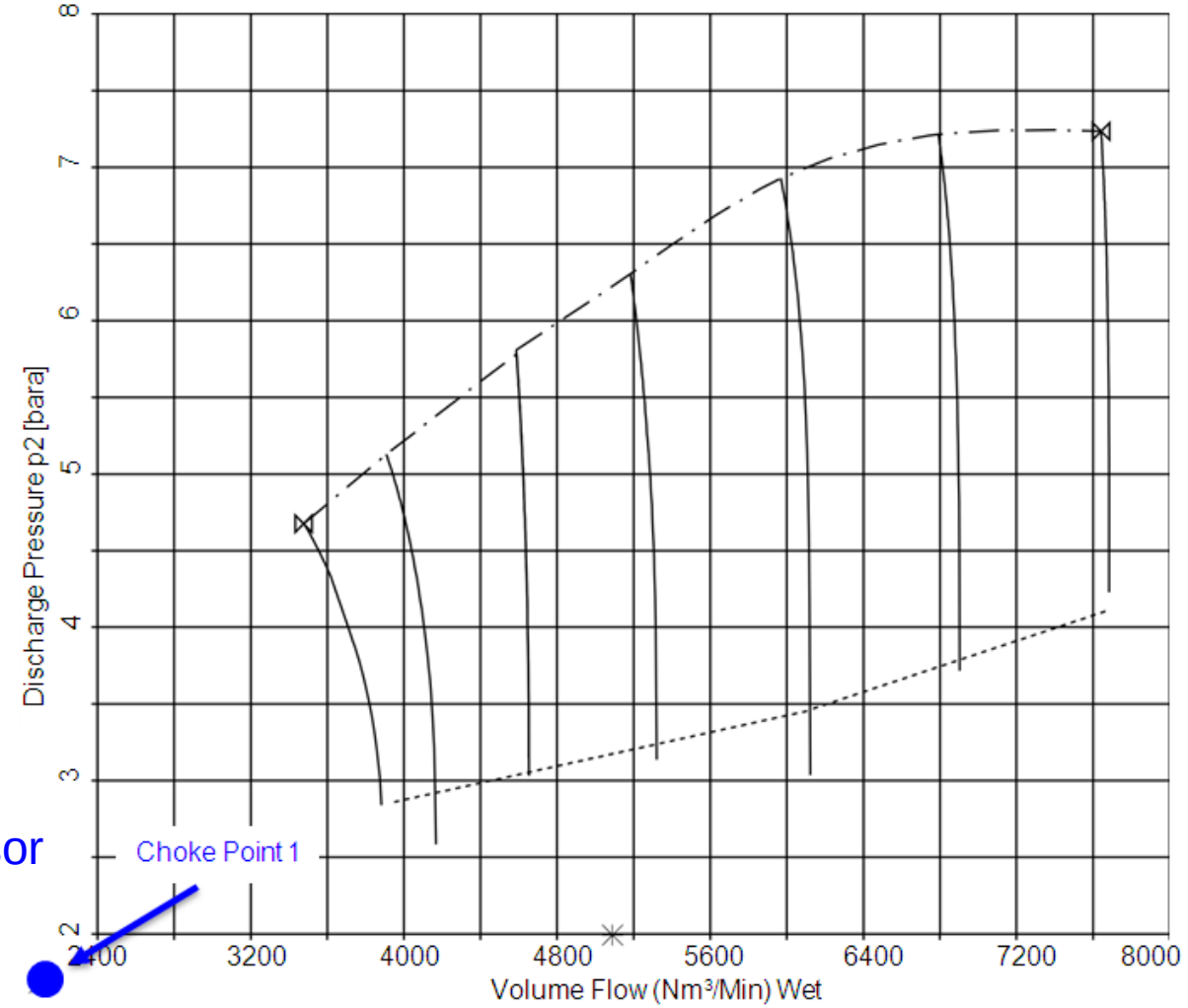


RCFA – Operation Data Evaluation

May – June :

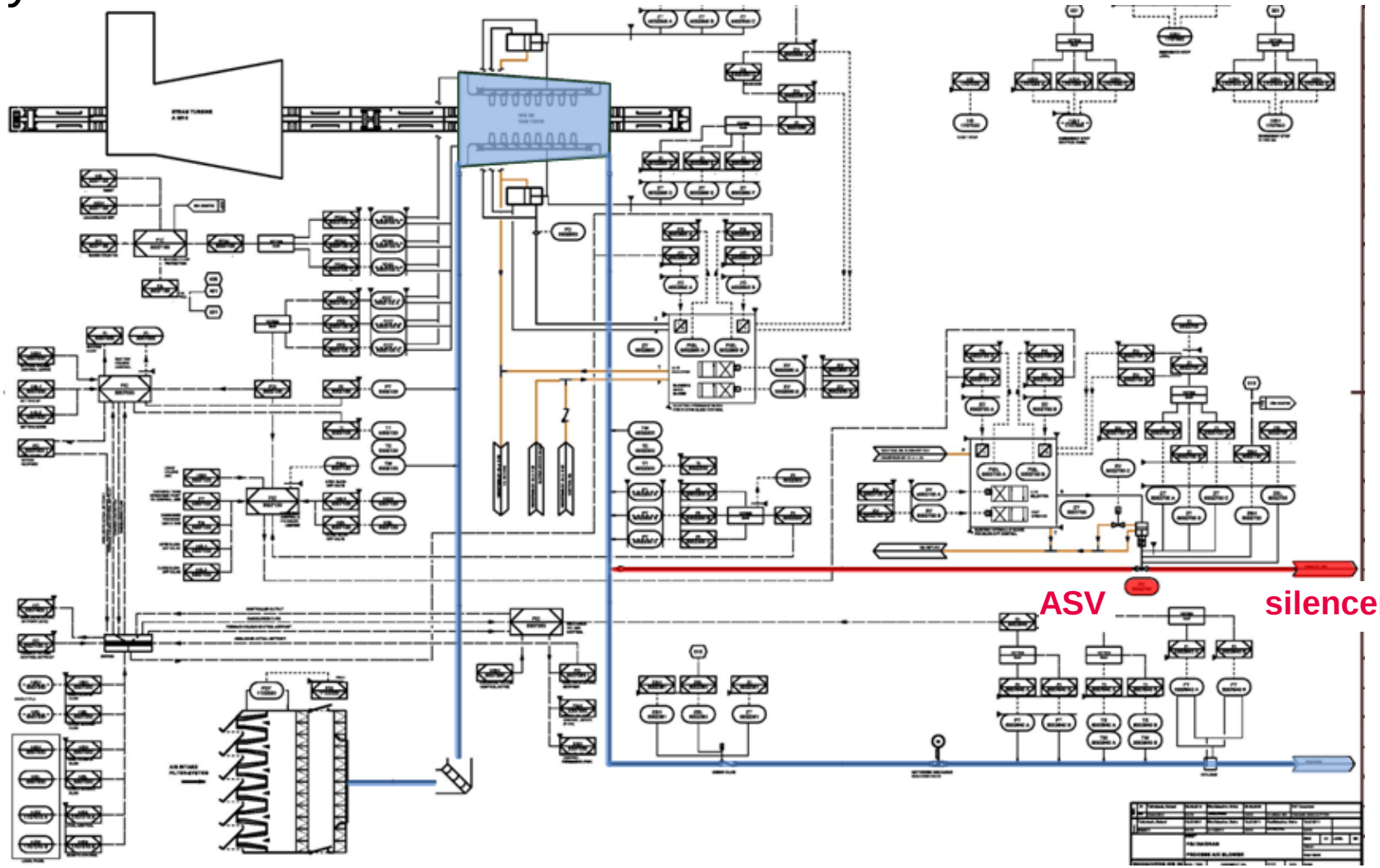
- operation at chokepoint 1 for several hundred hours
- standstill of compressor

Reason : warm-up of compressor



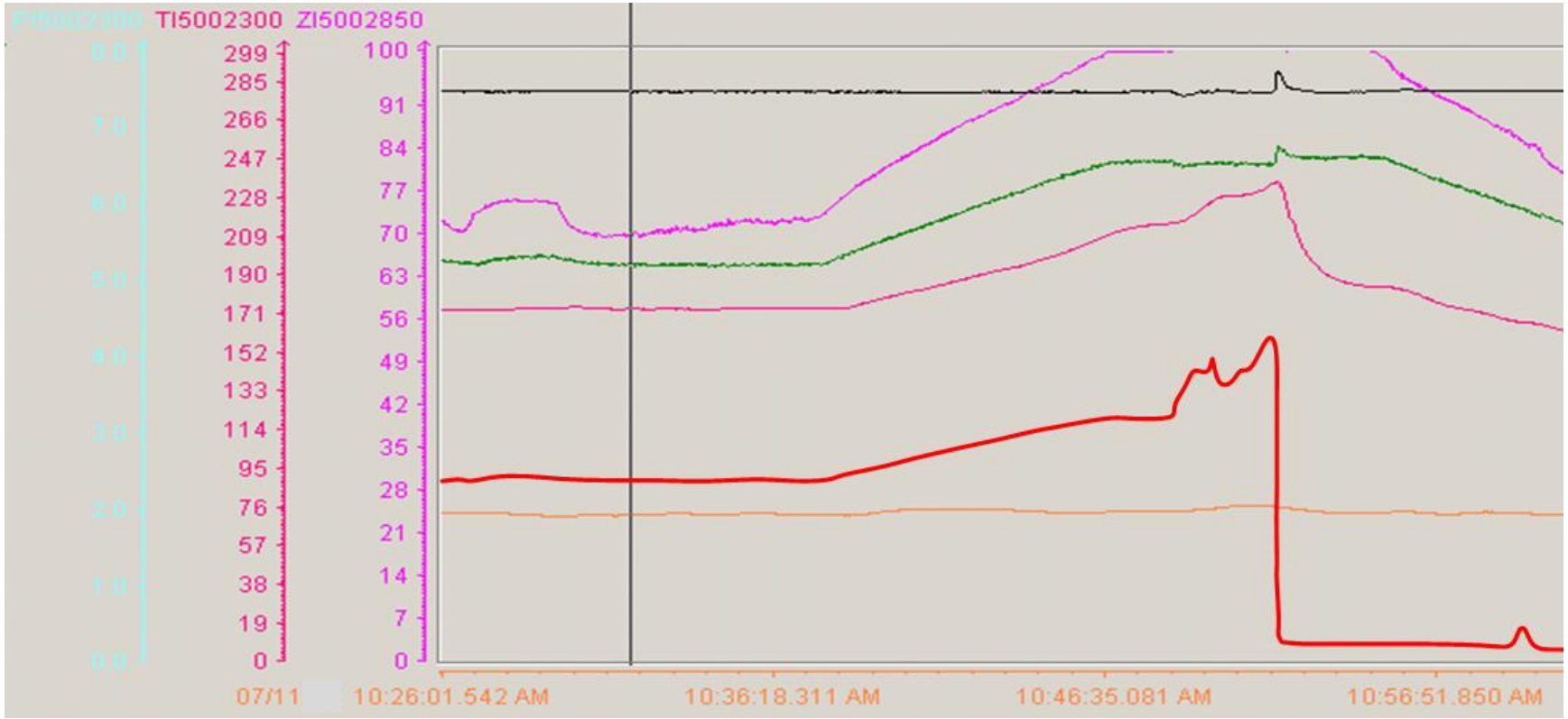
RCFA – Operation Data Evaluation

- July 11th : silencer failure



RCFA – Operation Data Evaluation

Silencer failure leads to a sudden pressure drop and a resulting negative pressure wave hits the compressor blading.



RCFA – Operation Data Evaluation

Result of silencer failure:

- operation at chokepoint 2 for approx. 8 hours (cumulative) from June 12th until July 31st

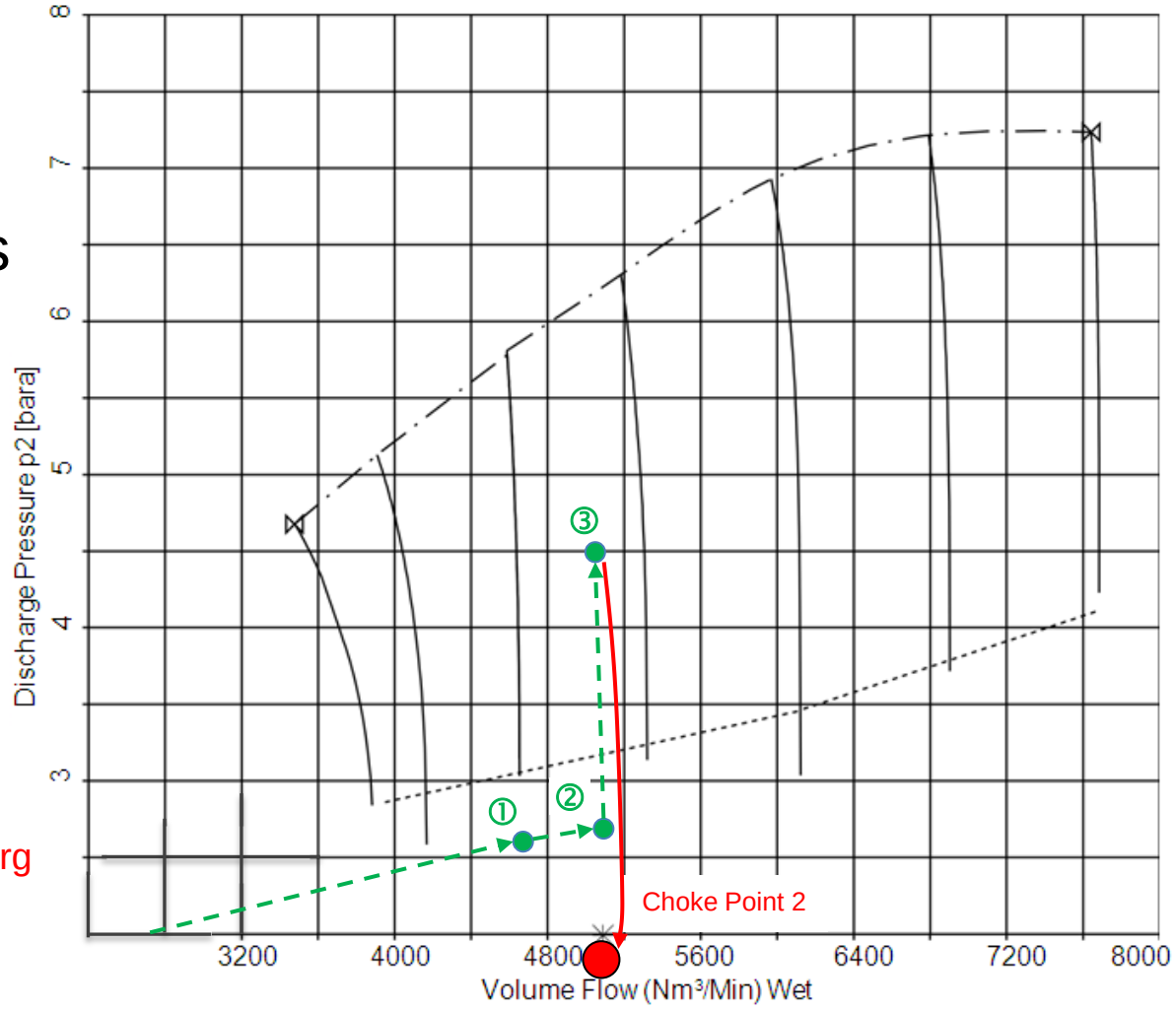
① - 100% Speed (1.5h)

② - Opening of IGV (4 min)

③ - Increasing of backpressure (1s)

- Silencer incident

④ - Dropping of backpressure to 0.2 barg

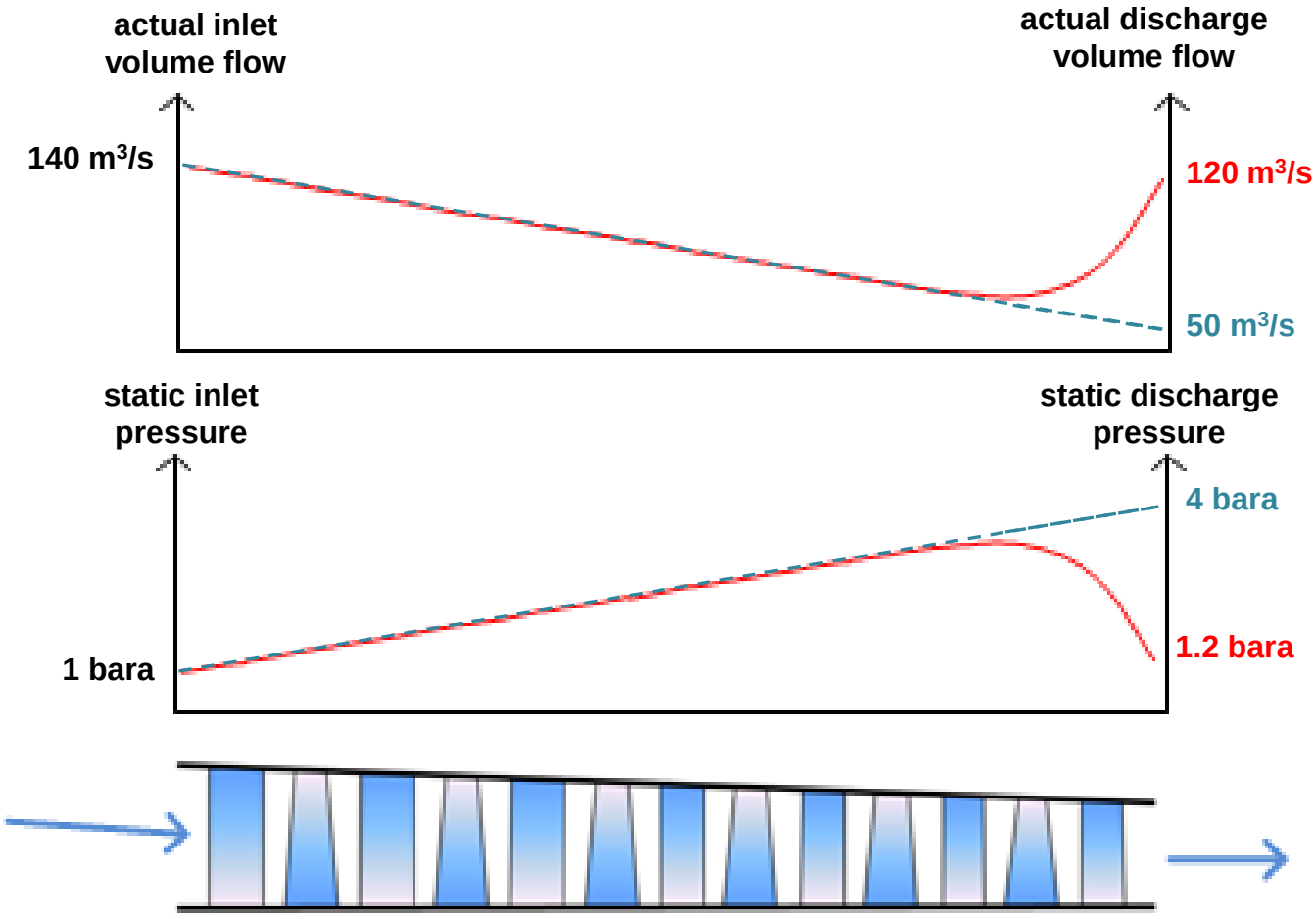


RCFA – Aerodynamic Investigations

choke operation: explanation

volume flow

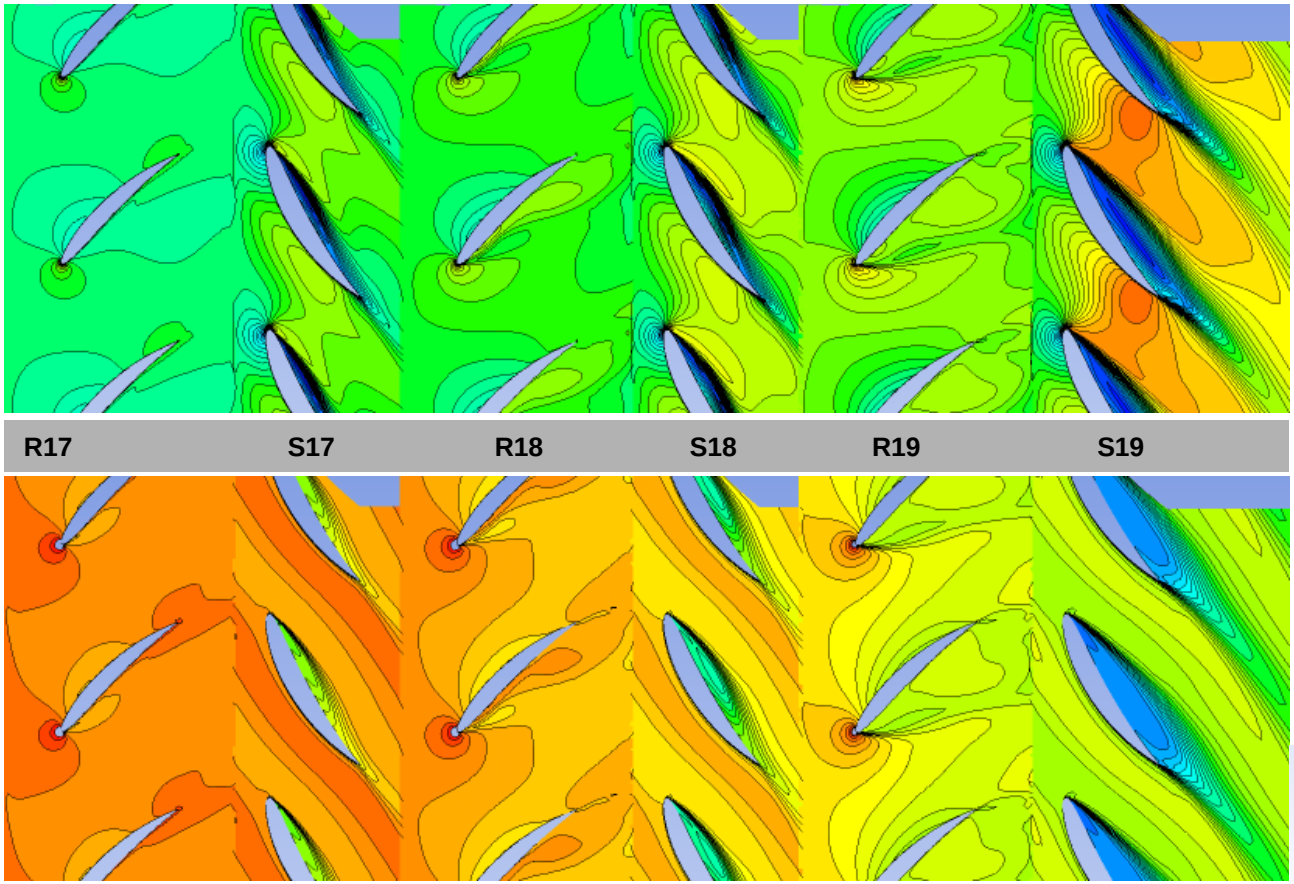
pressure

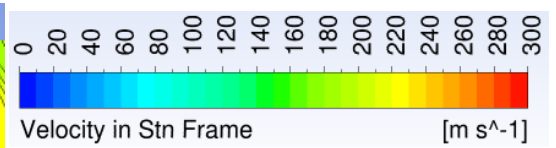


exemplary values only (qualitative)

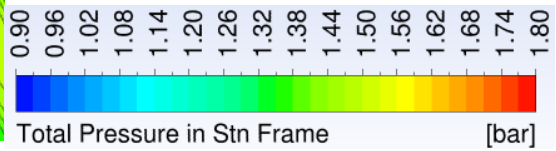
RCFA – Aerodynamic Investigations

choke operation: explanation



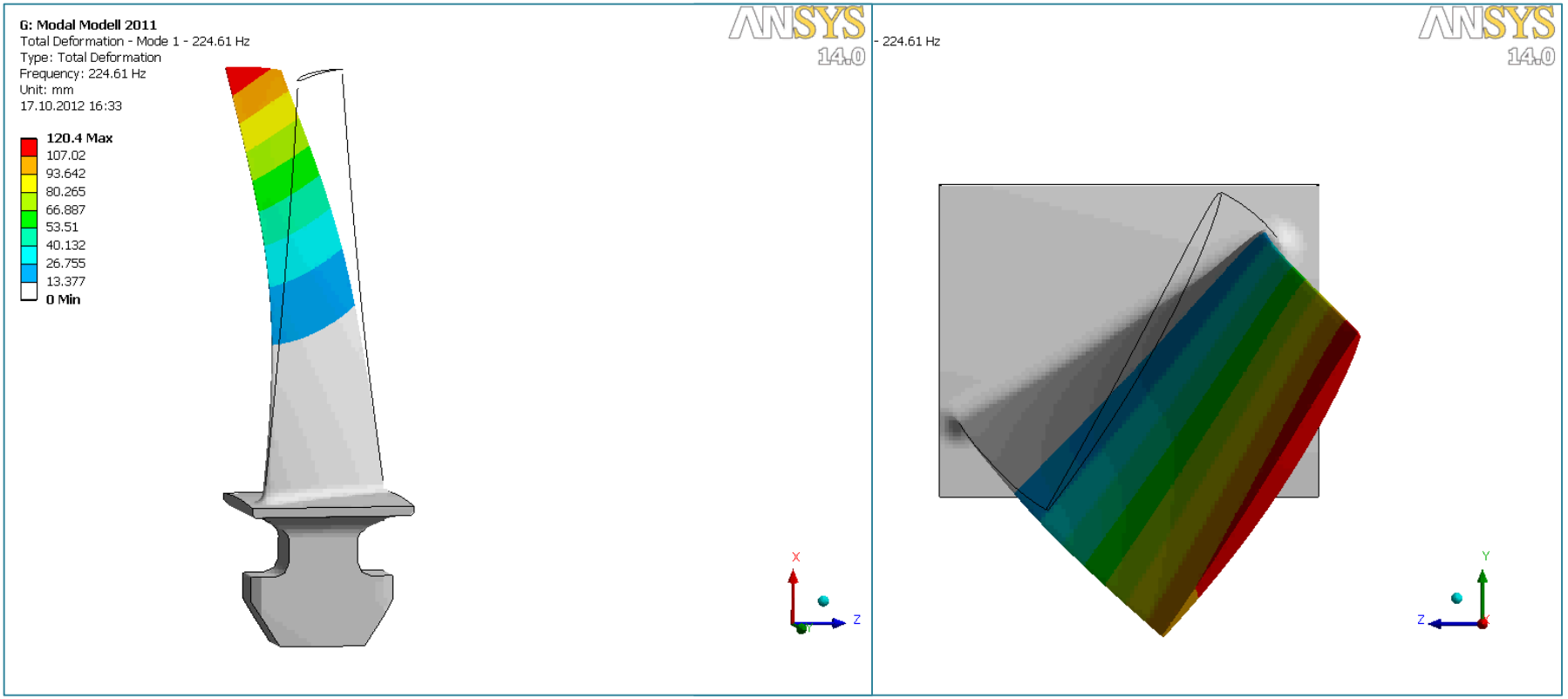


→ **specific flow conditions (stall), which can stimulate the natural frequencies of the blades**



RCFA – Aerodynamic Investigations

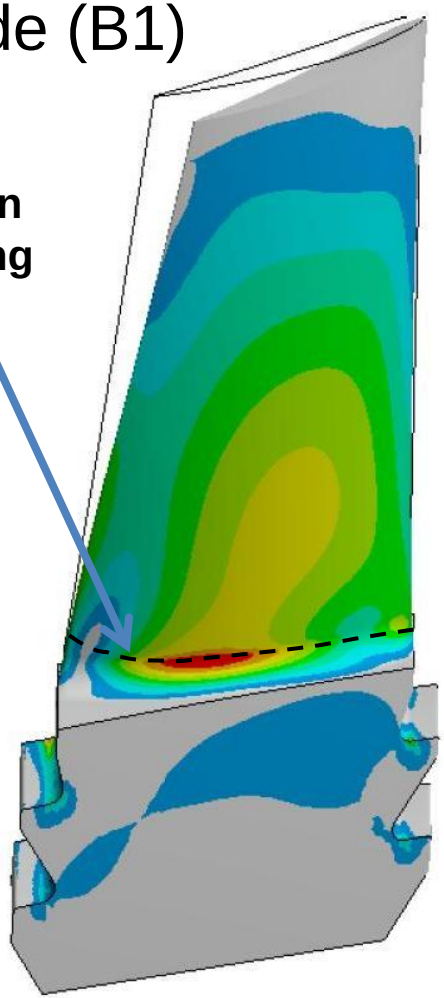
choke operation: first bending mode (B1)



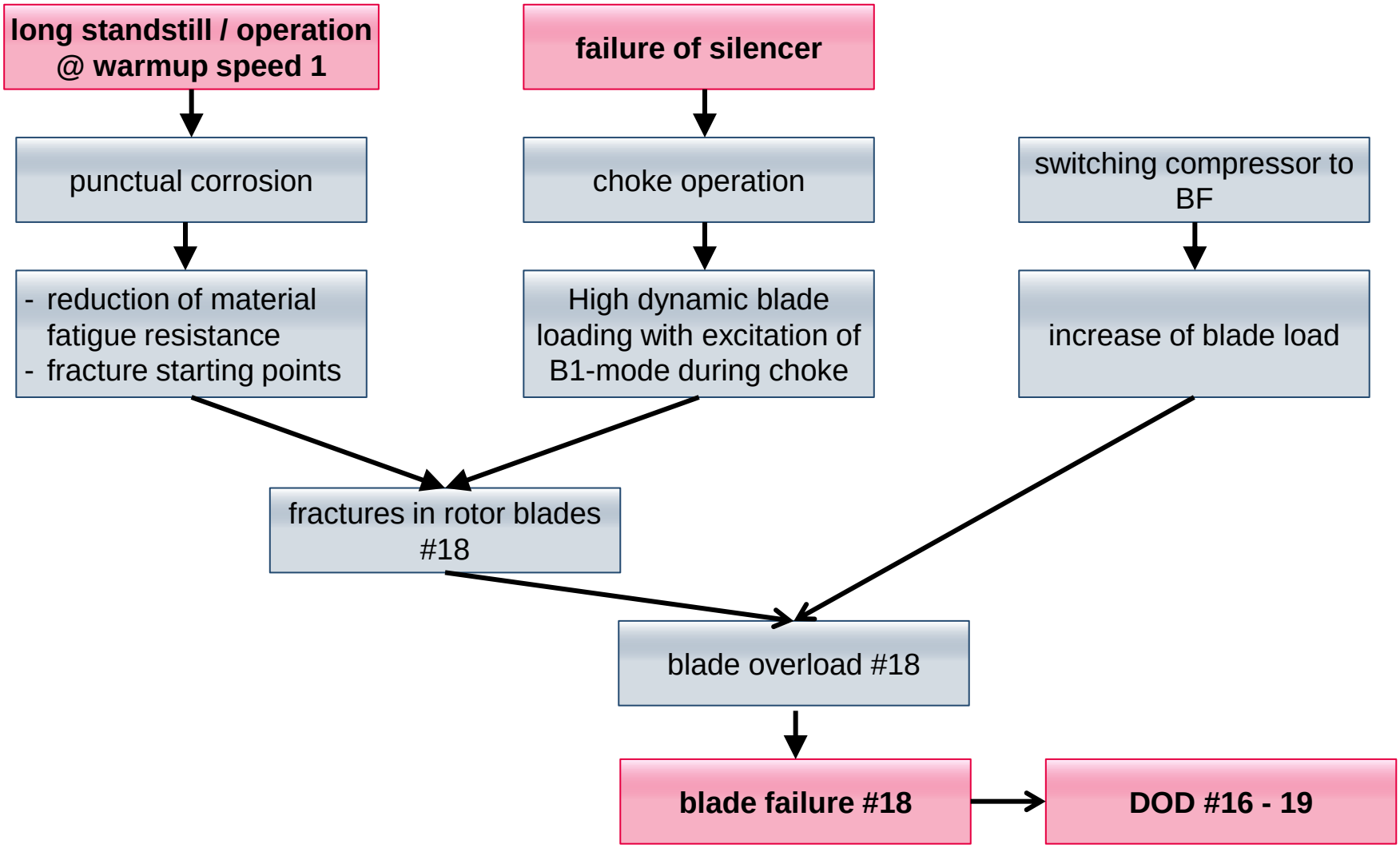
RCFA – Aerodynamic Investigations

choke operation:
first bending mode (B1)

airfoil cross section with highest bending moment



RCFA – Breakdown causes



RCFA – Countermeasures

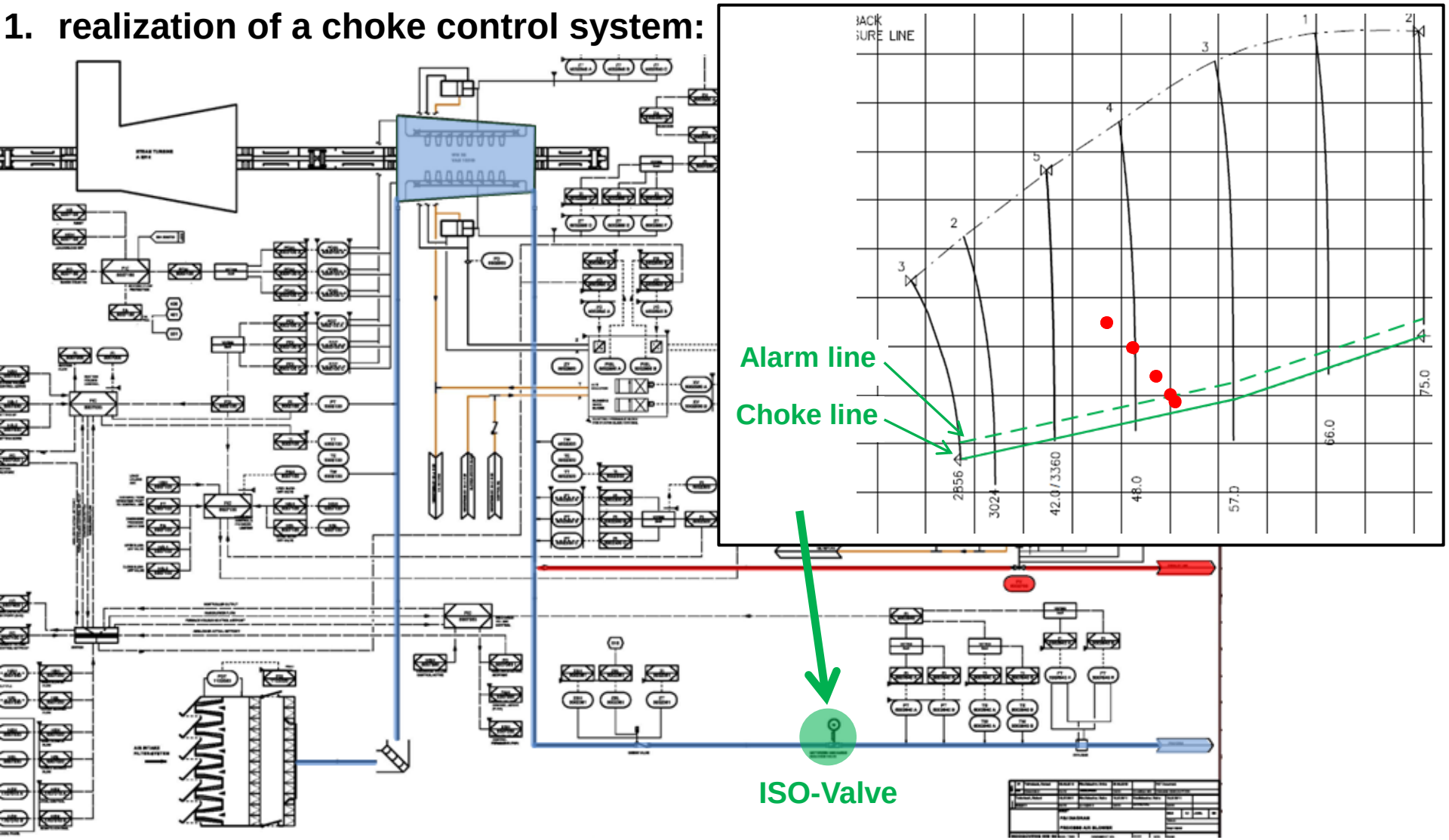
In order to avoid any further compressor breakdown due to above mentioned reasons, 3 countermeasures were implemented:

1. realization of a choke control system

   (see next slide)

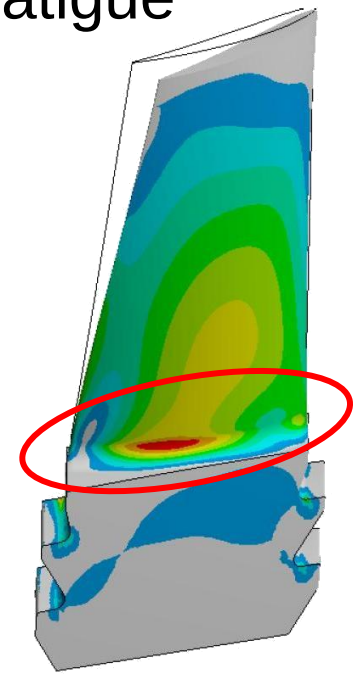
RCFA – Countermeasures

1. realization of a choke control system:



RCFA – Countermeasures

2. improved resistance against overload and fatigue fractures with modified rotor blade design
3. avoidance of corrosion attacks by application of an inorganic aluminum coating with chromate/phosphate inert sealant (rotor blades only)



Conclusion

- The encountered case was the consequence of the concatenation of many factors:
  - Choke operation
    - High load on blades
  - Corrosion

- Not only the surge but also the operation in (deep) choke is an issue for the reliability of an axial compressor

- To prevent any future damage appropriate countermeasures are necessary:
  - Choke control system
    - Increased blade thickness
  - Application of coating

Disclaimer

All data provided in this document is non-binding.

This data serves informational purposes only and is especially not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

Thank you very much for your attention

Questions ?