Design of gas turbine components

Siemens Energy AB, Finspång

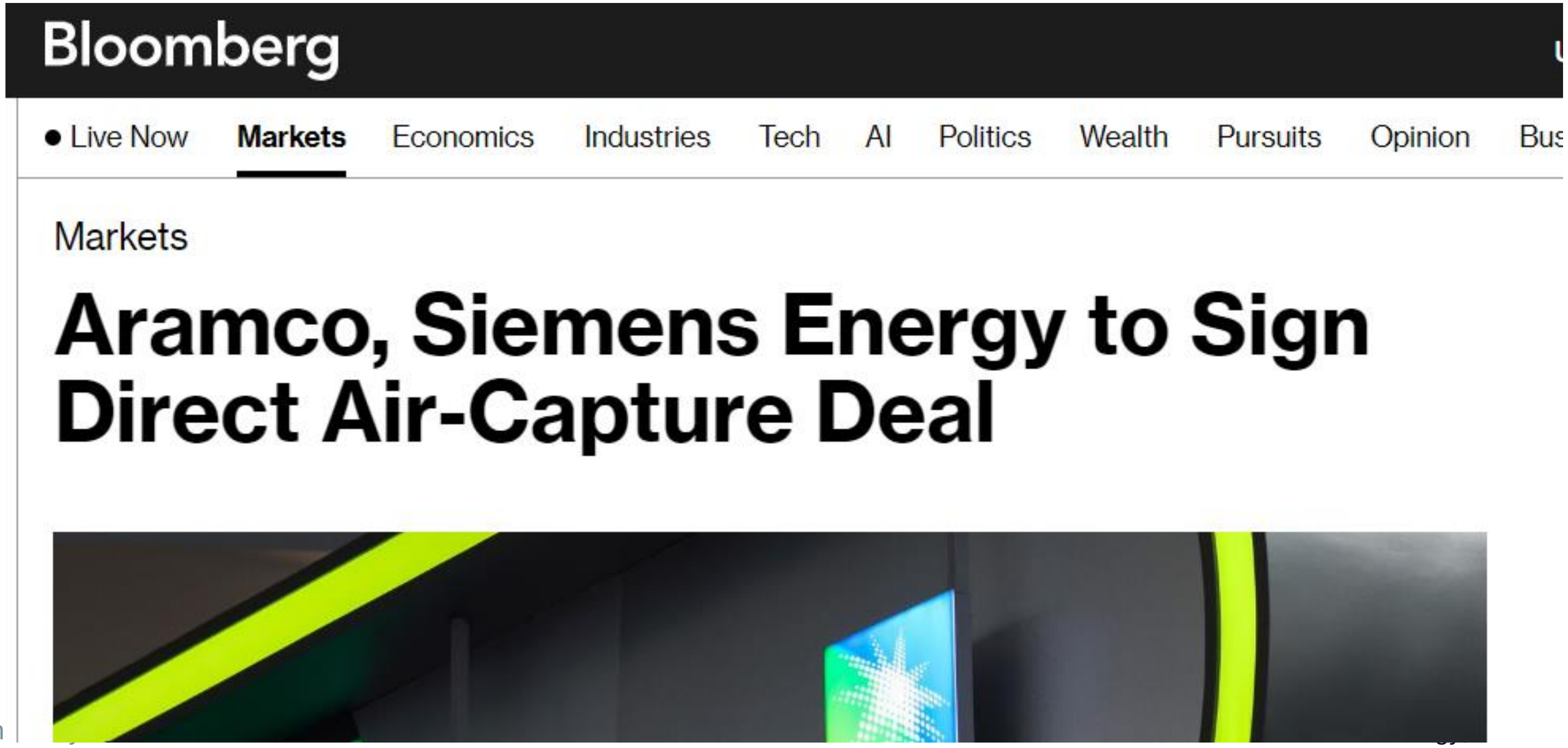
Siemens Energy AB, Finspång

- Siemens Energy ~1E5 employees
- Siemens Energy AB 3E3 employees

- 1496: Ironworks set up in Finspång
- 17th century: Manufacturing of canons
- 1913: STAL (Svenska Turbinfabriks AB Ljungström) steam turbine factory
- 1940’s: jet engine development -> industrial gas turbines
- 1960’s: STAL-LAVAL Turbin AB
- 1988: ABB STAL AB
- 1999: Alstom Power
- 2003: Siemens Industrial Turbomachinery AB
- 2020: Siemens Energy AB

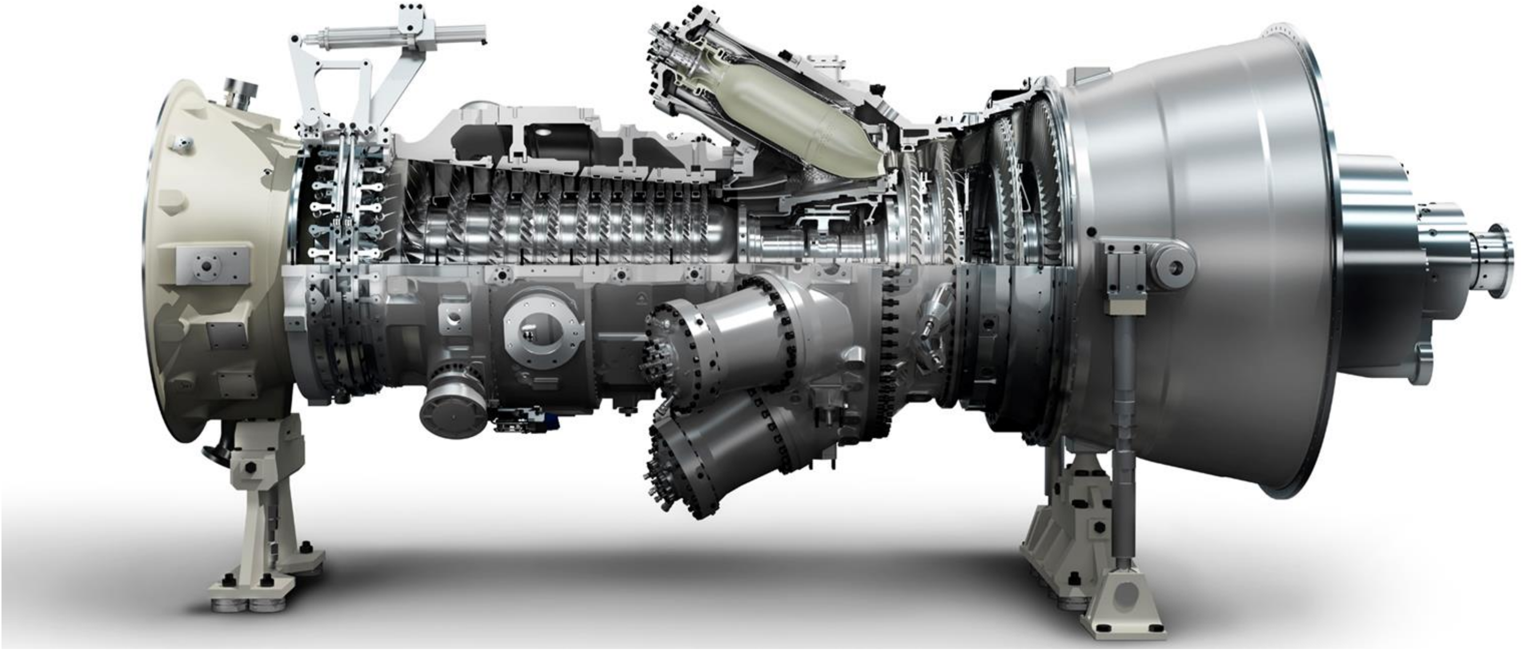
The role of Siemens Energy AB in a sustainable energy transition

- Gas turbines as a complement to renewable energy sources
  a. Flexible balance power
  b. Back-up power & grid stability
- Green fuels and hydrogen
- Carbon Capture



Content

- Design of turbine components
- Temperature calculations
- Mechanical integrity calculations



Design of gas turbine components

- 2000K
- 20bar
- Flow velocity: 800m/s
- Rotational speed: 550m/s

Gas turbine components development

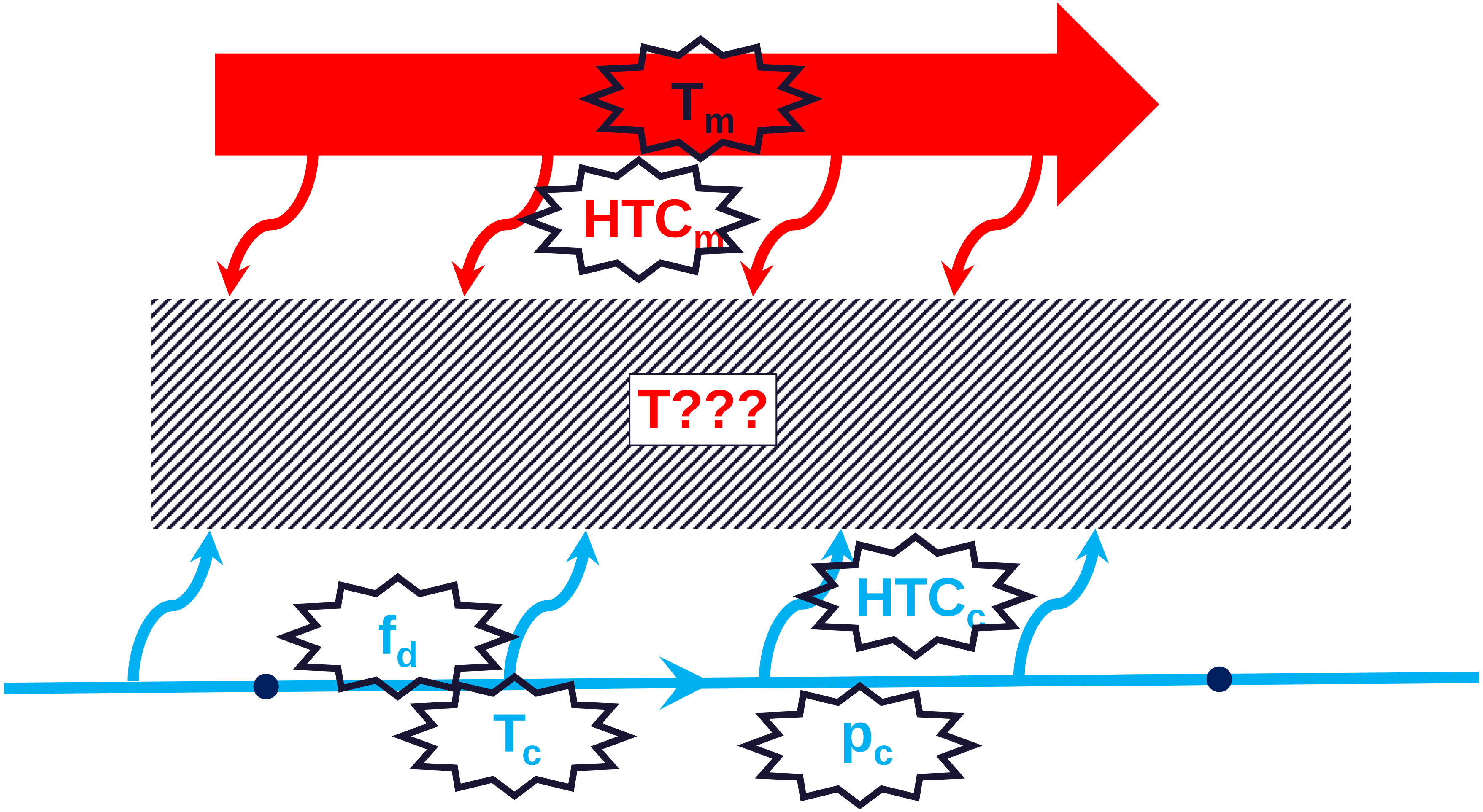
Aero calculations
(without film cooling)
→ Outer BC

Heat transfer calculations
→ Temperature distribution

Mechanical integrity calculations
→ Lifetime, LCF, oxidation, etc

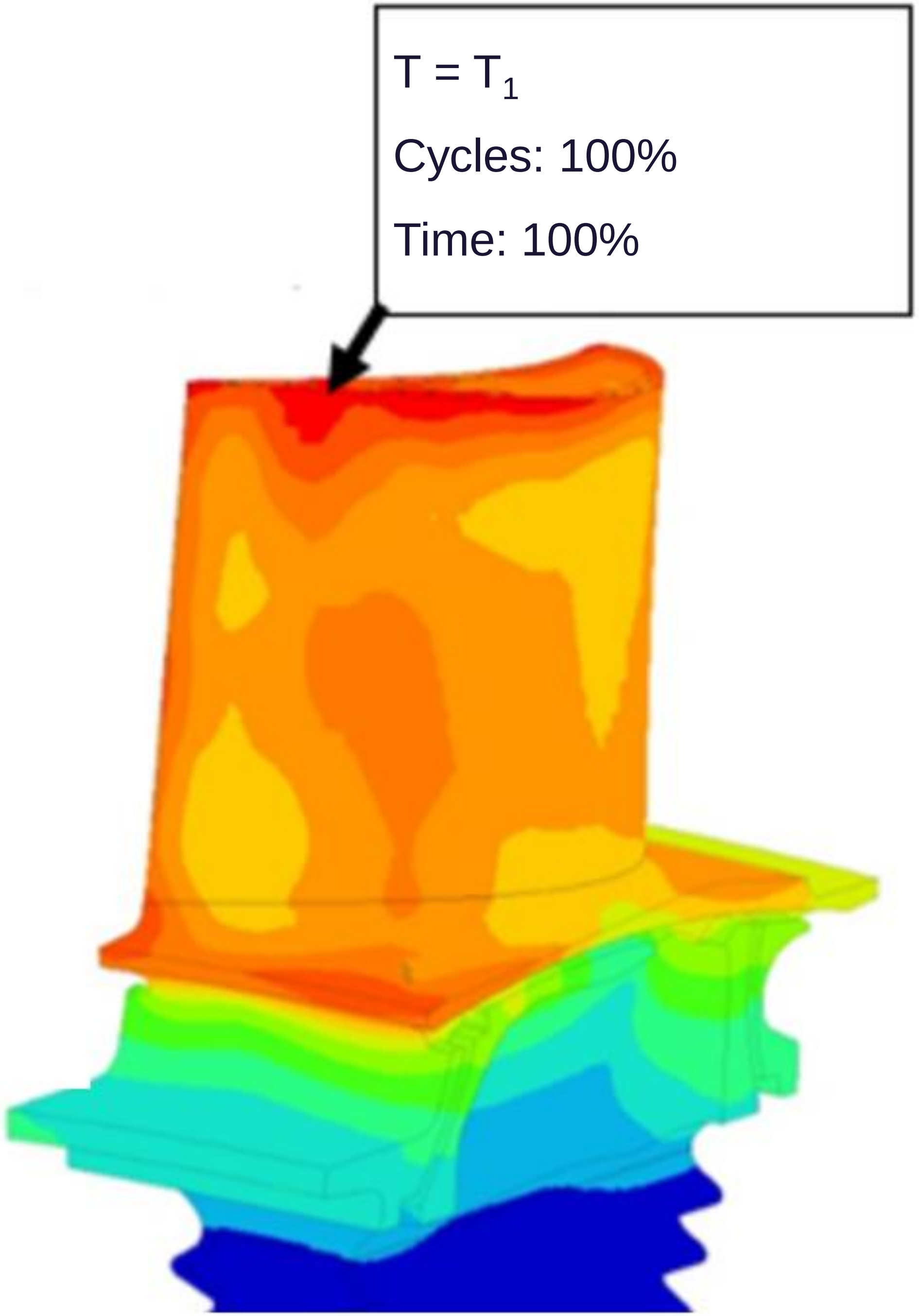
Temperature calculations

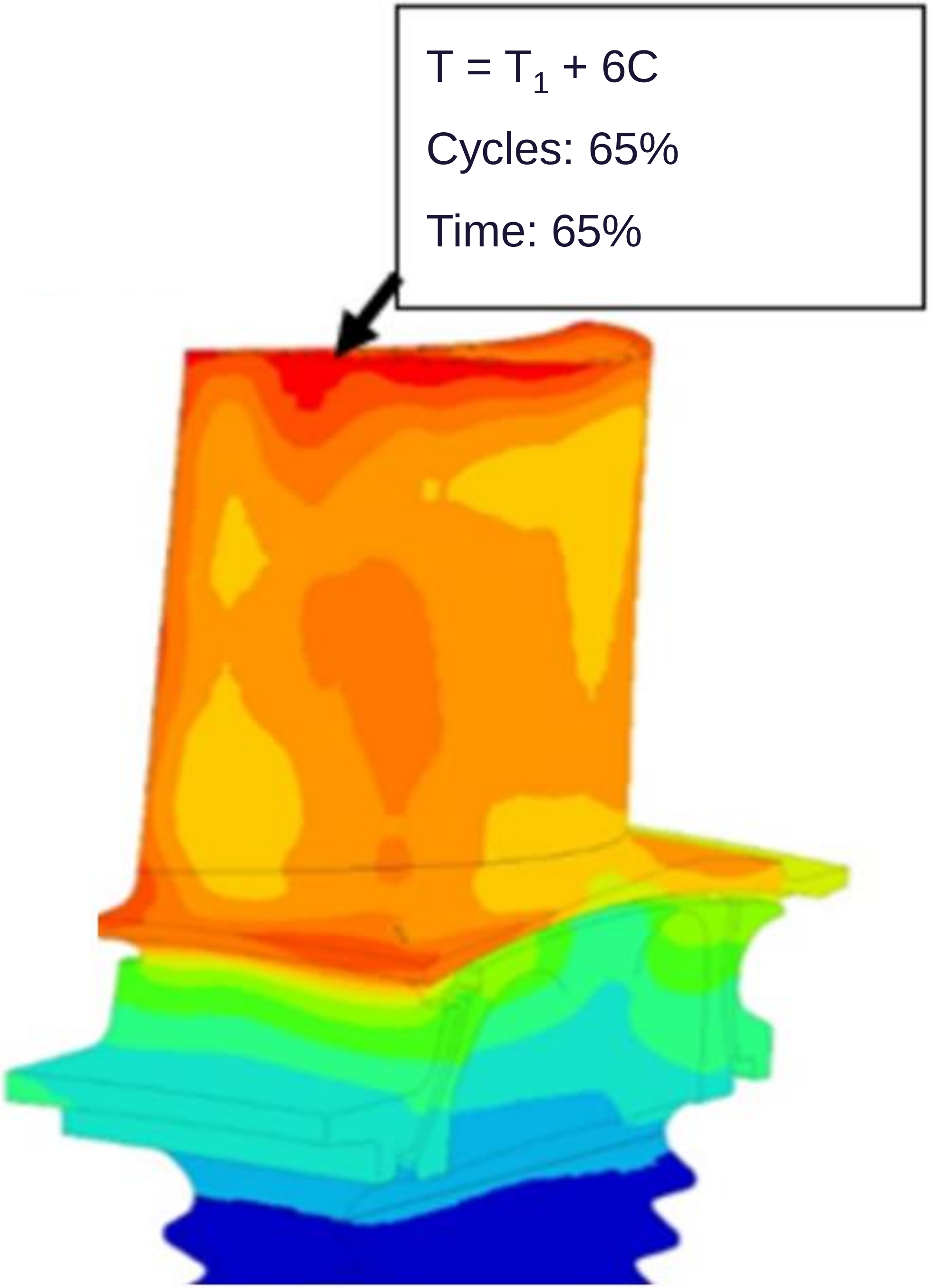
Temperature Calculations



Conjugate solver to calculate temperatures

C3D


T = T1
Cycles: 100%
Time: 100%


T = T1 + 6C
Cycles: 65%
Time: 65%

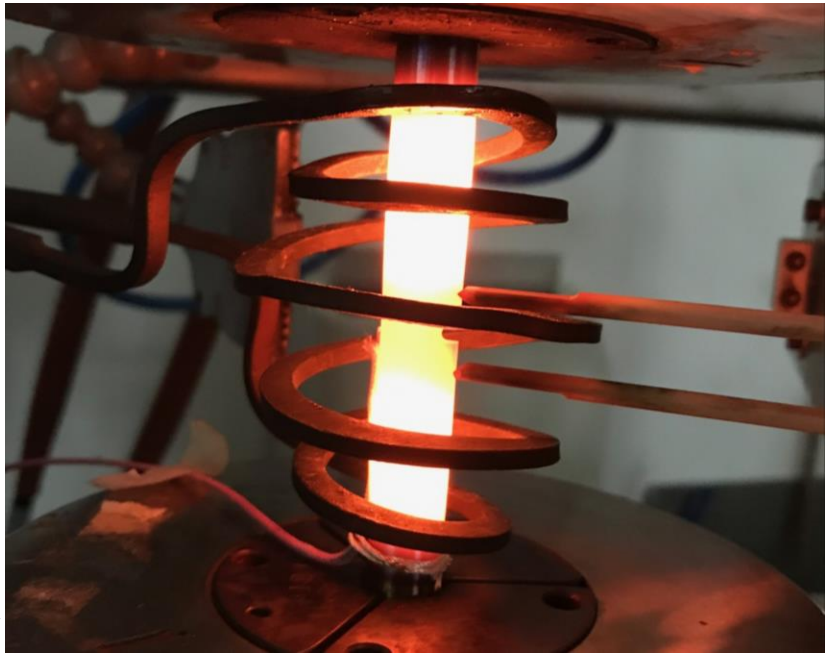
Mechanical integrity calculations

Gas turbines: design of components Mechanical integrity

Increased gas turbine efficiency can be reached by

- Increased firing temperature → Hotter combustor and turbine components
- Increased pressure ratio → Hotter rotor components and hotter cooling air
- Lower cooling air consumption → Hotter turbine components

Higher Gas turbine efficiency implies higher metal temperatures



Gas turbines: design of components Mechanical integrity

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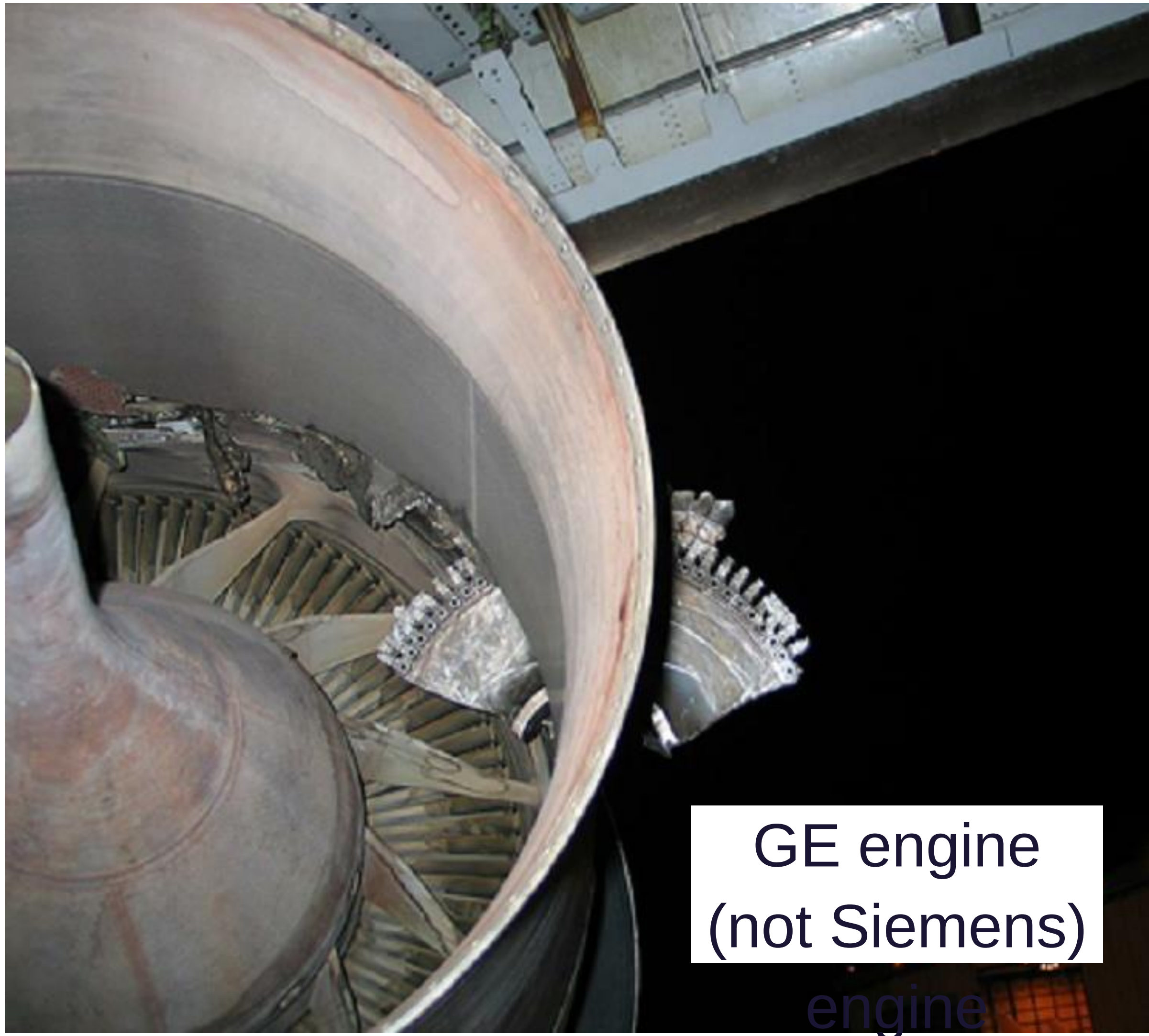
- Predicting the cyclic life of critical component is one of the more challenging issues in gas turbine design
- Component failure is extremely costly and can potentially lead to the loss of human life. Thus, avoiding failure is always a first priority
- The most common failure mode is probably material fatigue leading initiation and subsequent growth of cracks.
- Fatigue failure can have catastrophic consequences

Example



Gas turbines: design of components Mechanical integrity

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- The hottest metal temperatures of a gas turbine blade can be well over 1000°C

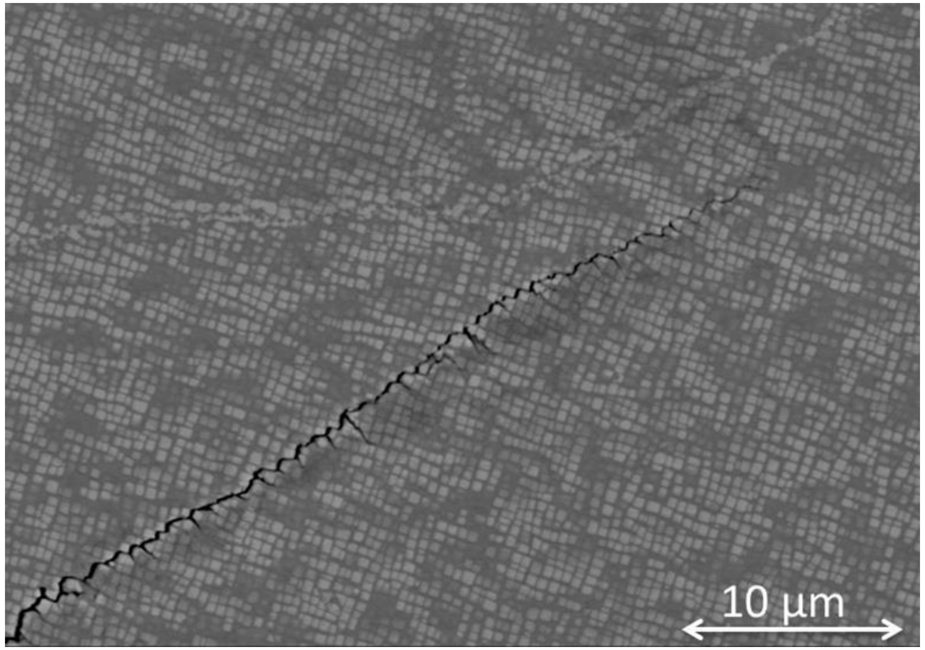
- Superalloys are often used in these applications and are currently the only class of materials with the right combination of mechanical properties to be widely used in these components.

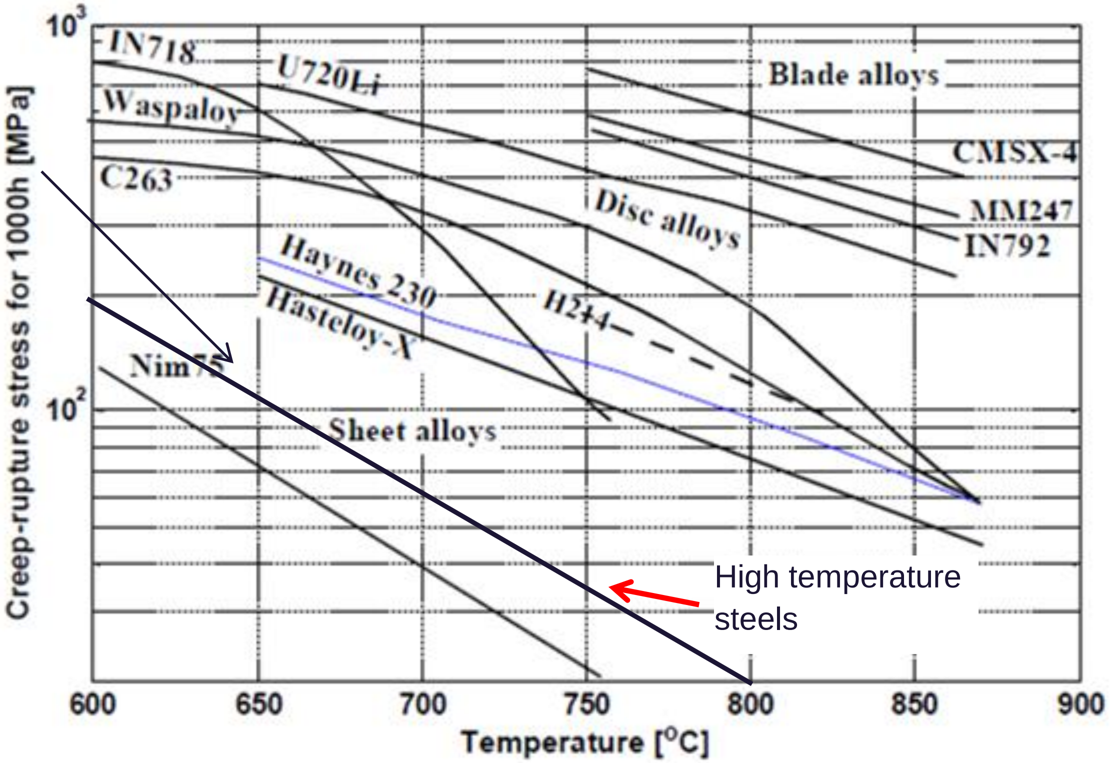
- Superalloys exhibit excellent mechanical properties at high temperatures such as:
  - Exellent creep behaviour
  - Good oxidation and corrosion resistance
  - High strength up to very high temperatures

Gas turbines: design of components Mechanical integrity

- Superalloys are often based on Nickel and have a complex alloy composition and microstructure

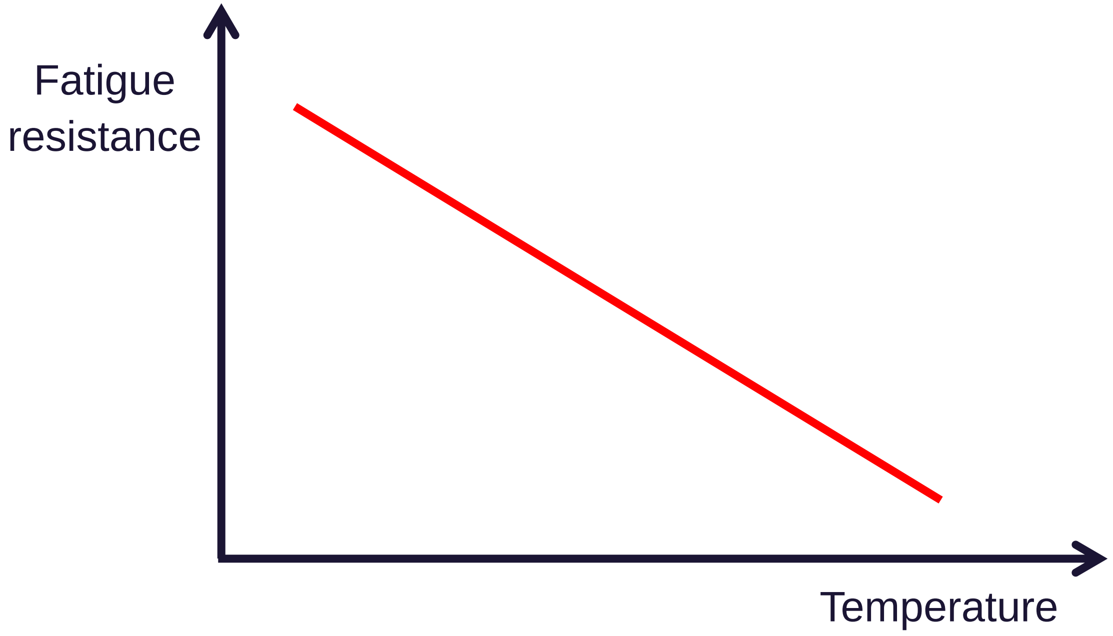
- They often get their high strength from precipitation strengthening which forms secondary phase precipitates such as gamma prime

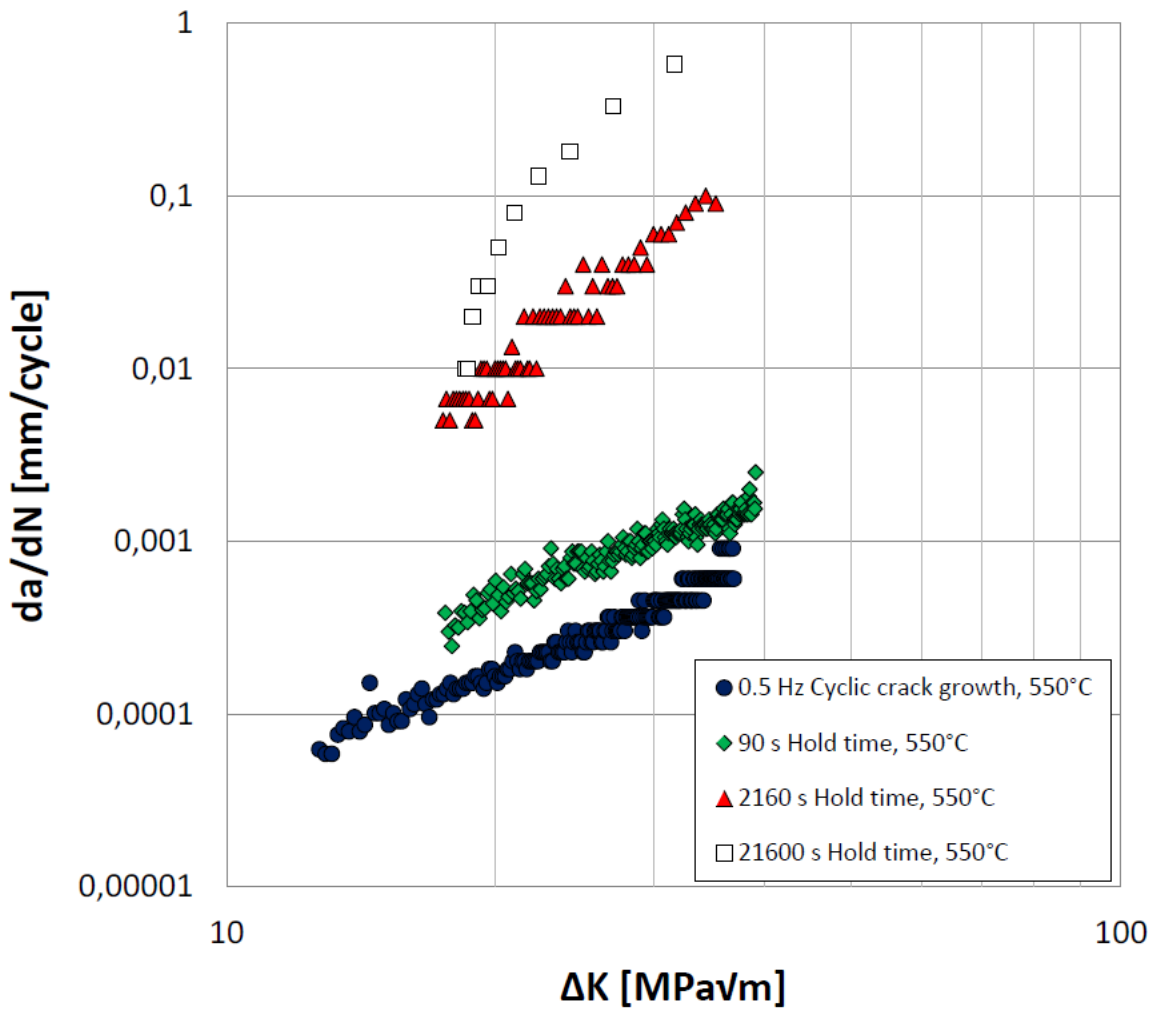




Gas turbines: design of components Mechanical integrity

- Unfortunately, the fatigue properties of superalloys decrease with increasing temperature
- At high temperature, time dependent effects such as creep, oxidation and corrosion play a significant role





Crack growth results with hold times for IN718 from my dissertation

Gas turbines: design of components Mechanical integrity

- Gas turbine component lifing it is often difficult because of
  - Temperature driven loads
  - Complex geometry

- 3D crack growth tools with Finite element simulations solve this for us