Testing procedures for the evaluation of strain age cracking in nickel based superalloys

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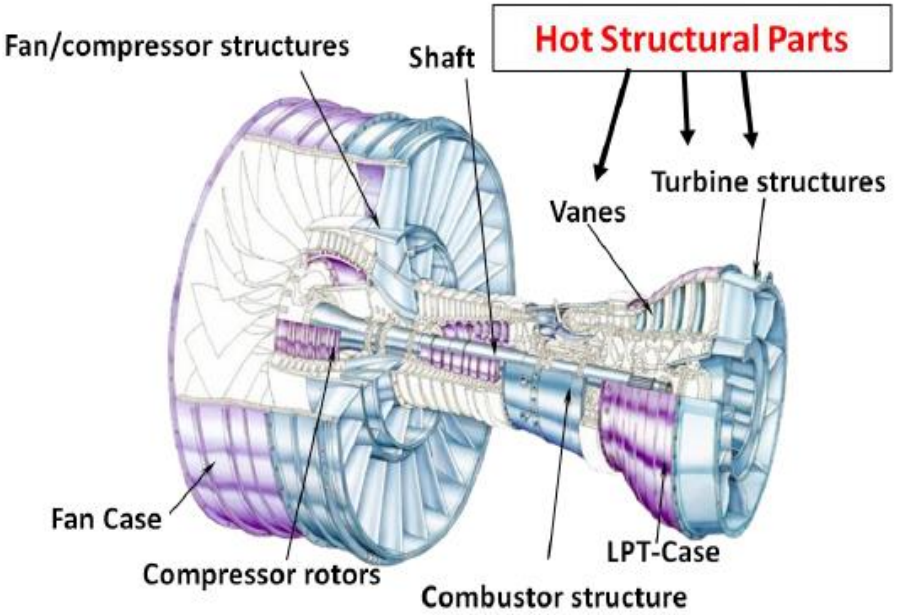
Superalloys in aircraft engines

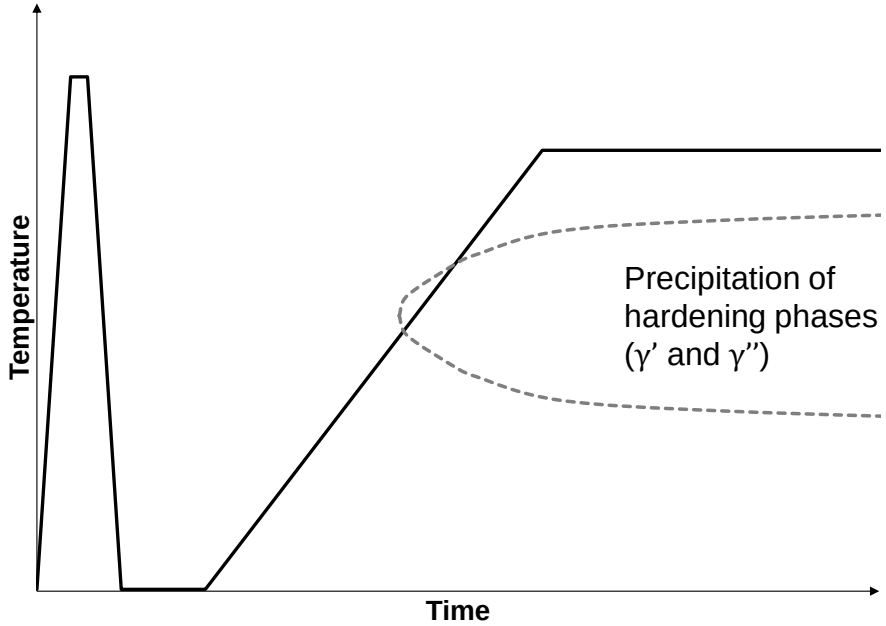


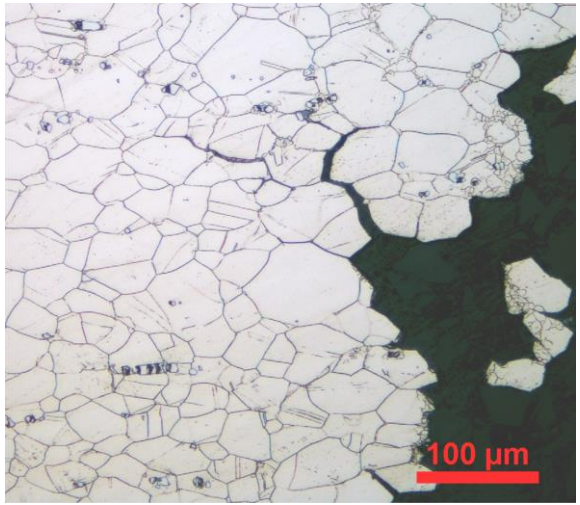
Motivation for strain age cracking research

- Production via assembly approach
  - Small cast and wrought parts joined together by welding

- Increased service temperature
  - Higher engine efficiency
  - More severe environment from materials point of view

Strain age cracking (SAC)



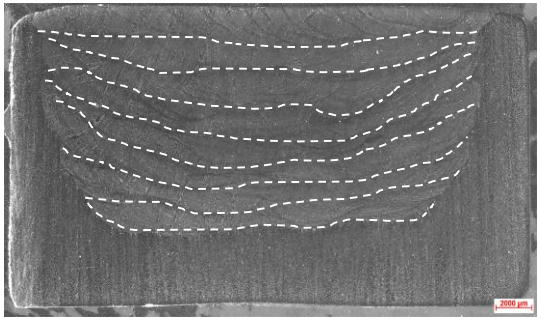


Weldability testing

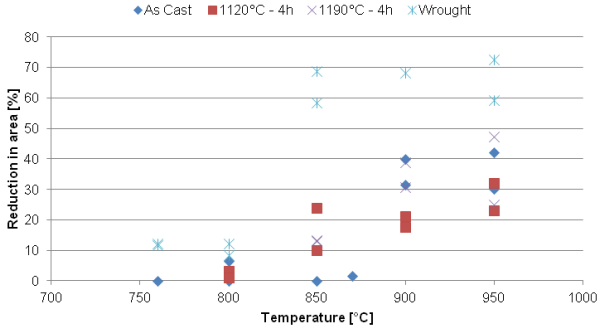
- No standardised test method exists for strain age cracking
- A large number of tests has been developed
- Often poor correltion between methods

Weldability testing

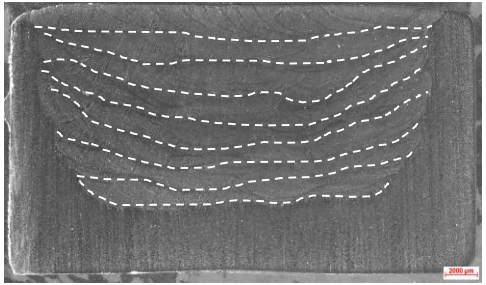
- Representative tests



- Simulative tests



Representative tests



- Often used in conjunction with repair welding
- Provides information on material performance
- Test mainly qualitative, but quantification possible to some extent
- Does not provide much insight into mechanism
- Can complement simulative tests

Simulative tests

- Tests that simulate the conditions present during welding
- Mostly mechanical testing at elevated temperature
- Testing under controlled conditions
- Quantified information on influencing parameters (e.g. restraint) is available
- Results are more universally applicable than those from representative tests

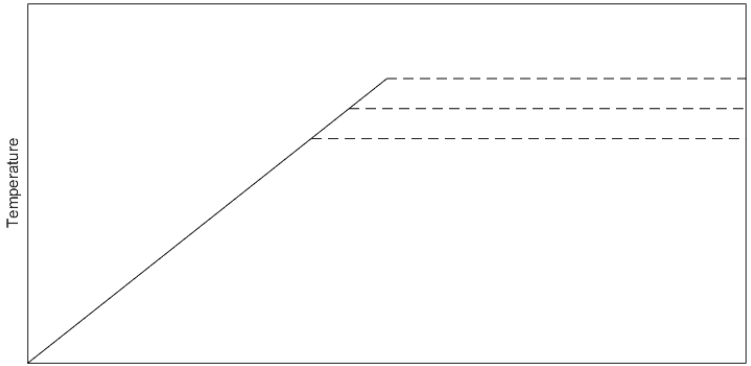
Simulative tests

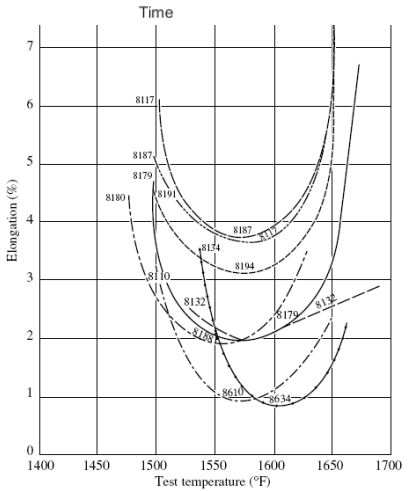
Constant load rupture tests (CLR)	• Time to failure measured • Does not predict well
Stress relaxation tests • Isothermal • Anisothermal	• Hard to create material rankings • Can provide insight into ongoing mechanism
Stress to fracture tests	• Does not indicate resistance towards SAC
Tests measuring ductility	• Can be used to rank materials • Different methods exist

Simulative tests

Constant heating rate test (CHRT)

- Simulates post weld heat treatment (PWHT)
- Ductility is measured to create material ranking
- Material rankings can be created
- Does not include HAZ microstructure



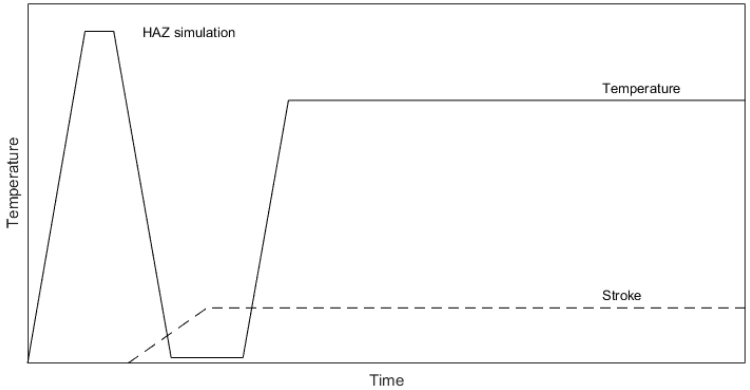


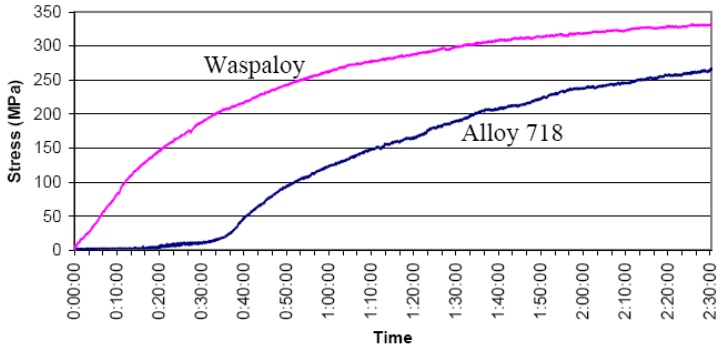
J. B. Carlton and M. Prager. *Variables Influencing the Strain-Age Cracking and Mechanical Properties of René 41 and Related Alloys*. WRC Bulletin 1970;150:13–23.

Simulative tests

Combination with stress relaxation

- Includes HAZ and stress relaxation
- Includes restraint
- Very fast heating rate to PWHT temperature
- Ductility measured after 8h aging time



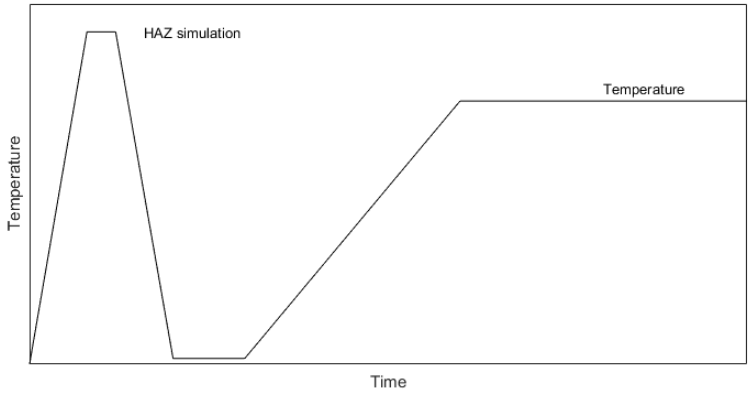


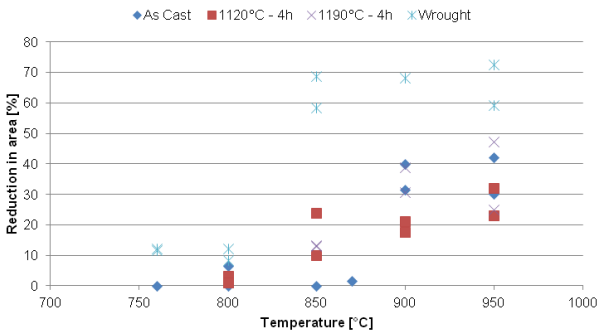
S. J. Norton and J. C. Lippold. *Development of a new Test Technique to predict Postweld Heat Treatment Cracking*. EWI Report No. MR0219; 2002.

Simulative tests

Modified CHRT

- Includes HAZ simulation
- HAZ simulation yields information on HAZ performance
- Does not include restraint





J. Andersson. *Weldability of Ni-Based Superalloys*. Proceedings of the 8th International Symposium on Superalloy 718 and Derivatives, The Minerals, Metals & Materials Society; 2014, p. 249–62.
F. Hanning. *Strain Age Cracking of Nickel Based Superalloys*. Master Thesis. Chalmers University of Technology, 2015.

Summary

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Representative tests	Represent actual welding conditions	Large scatter Hard to quantify results No insight into mechanism
Simulative tests	Enable precise parameter control Lower scatter Reproducible	Do not cover all aspects of SAC in single test

- Numerous tests have been developed
- No universally applicable method exists to cover all aspects of SAC
- CHRT type test seems to be best choice in terms of simplicity and reproducability
  - Should include HAZ simulation
- Combination of different tests is needed to obtain a deeper understanding of ongoing mechanisms

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Thank you!