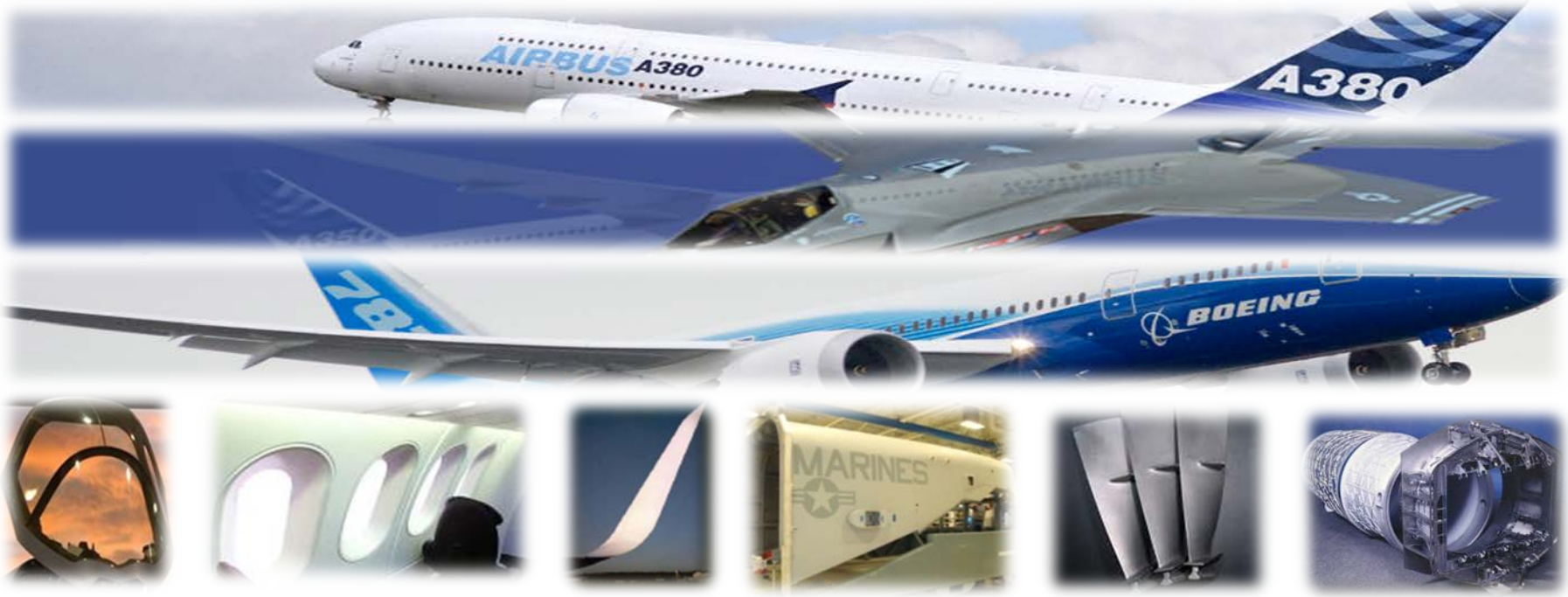
GKN AEROSPACE



Strain age cracking in nickel based superalloys (KME 706)
Hot Cracking in High Temperature Materials (KME 719)

HTC/KME research symposium
March 21-22, 2017

Fabian Hanning, Sukhdeep Singh, Joel Andersson & Lars Nyborg

Strain age cracking in nickel based superalloys KME 706

Fabian Hanning, Joel Andersson & Lars Nyborg

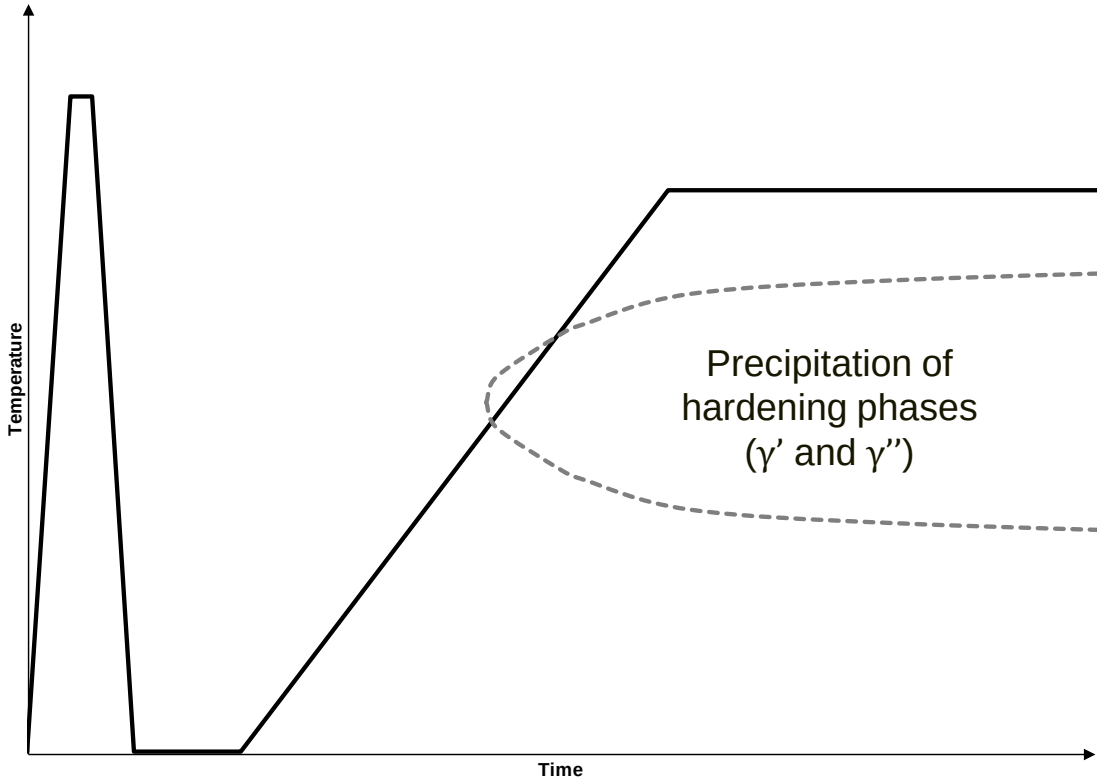
Aim of KME 706

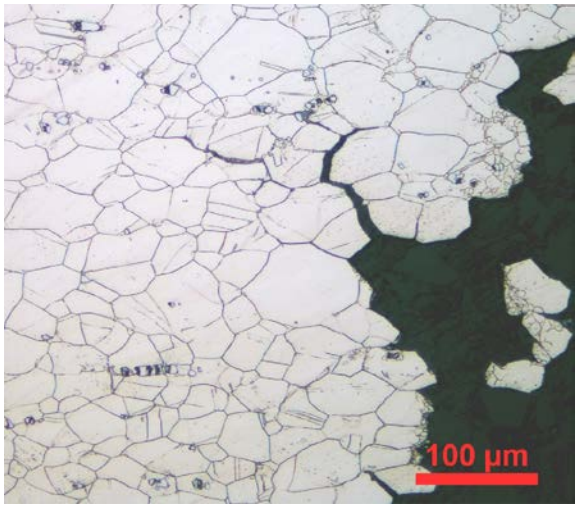
- **Provide a better understanding of ongoing mechanisms in Strain age cracking (SAC)**
  - Which influencing factors exist
  - How can these be influenced/ controlled
  - How can SAC be prevented?
  - Development of a testing procedure to assess the susceptibiliy of nickel-based superalloys towards SAC

Strain age cracking

- **Occurs specifically in precipitation hardening nickel based superalloys**
- **Cracks form during heating to post weld heat treatment**
  - Warm cracking phenomenon, as no liquid phase is involved
- **Influenced by**
  - High temperature
  - Precipitation of hardening phases
  - Residual stresses

Strain age cracking (SAC)





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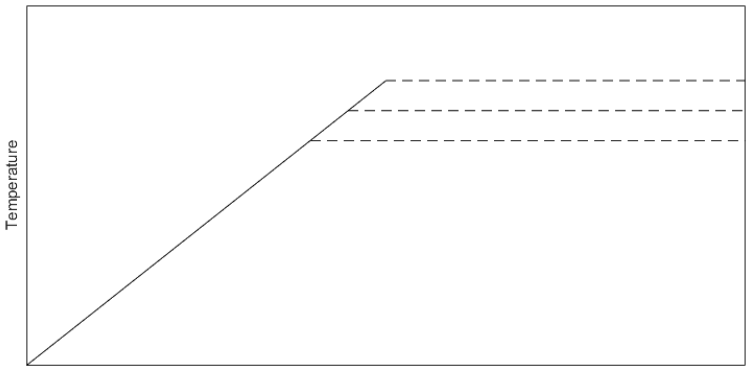
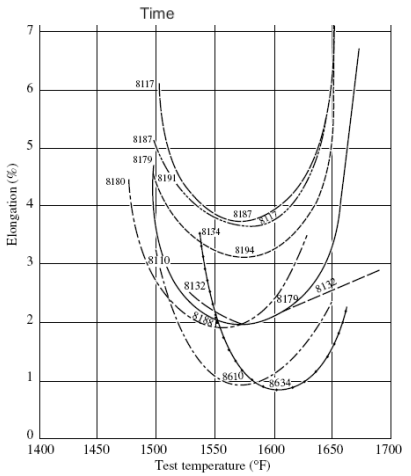
Simulative tests

- **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.

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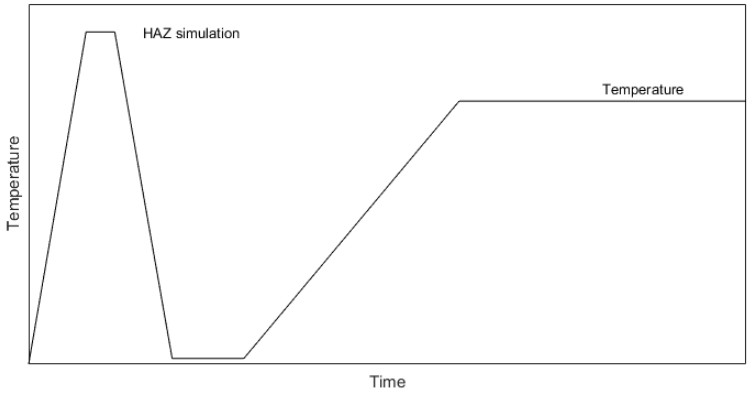
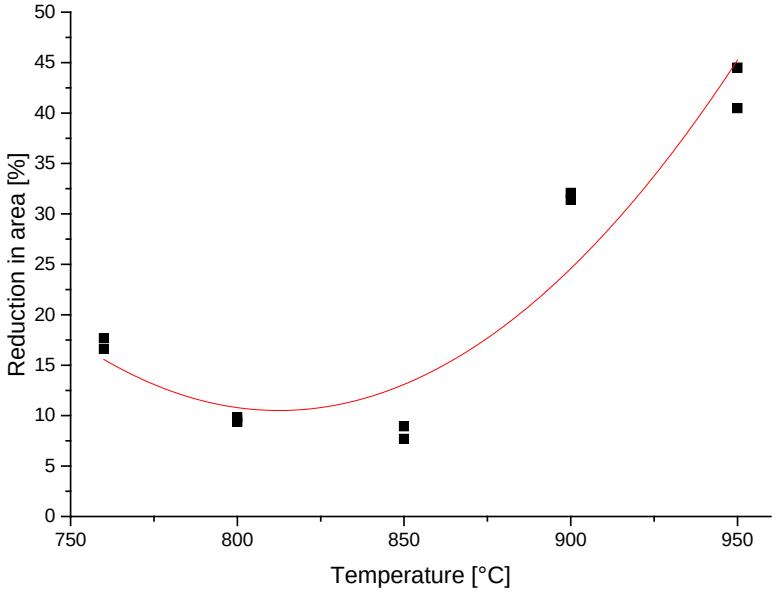
Modified controlled heating rate test

- Includes HAZ simulation
- Can be used for material rankings





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.

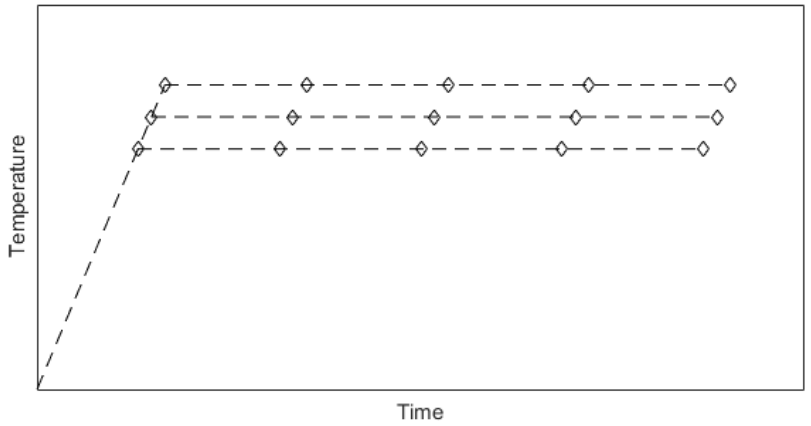
Why another test?

- **Advantages of constant heating rate test**
  - Ease of use
  - Measure for relative performance
  - Material rankings can be created

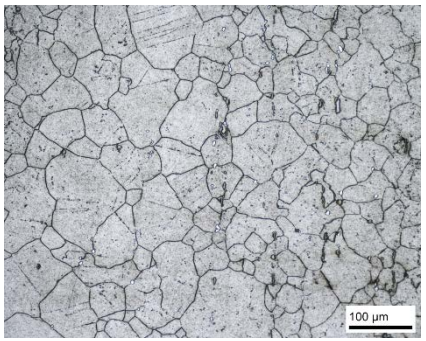
- **Disadvantages**
  - Does not provide insight into mechanism (influence of precipitates)
  - Does not account for heating rate/ exposure time

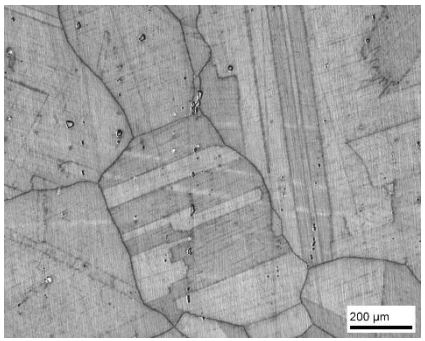
Ongoing work

- Heating rate 1000°C/s
- Holding time from 5s to 1800s
- Stroke rate 50mm/s
- Cooling rate >50°C/s



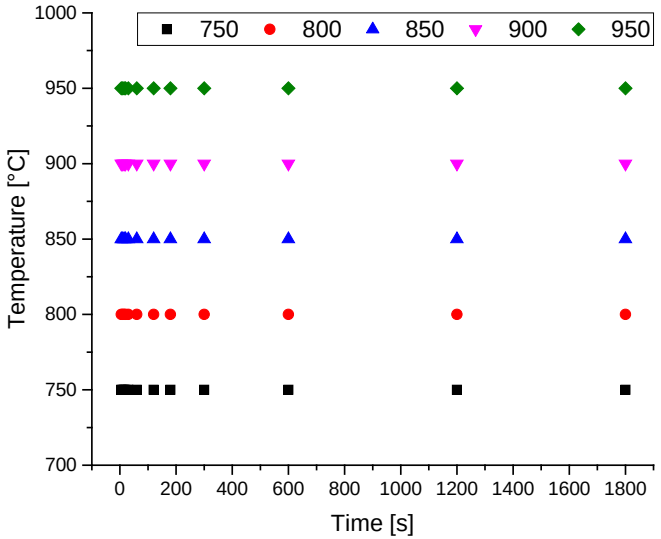
- Material: wrought Haynes 282
  - Solution annealed
  - 1150°C 2h (large grain size)





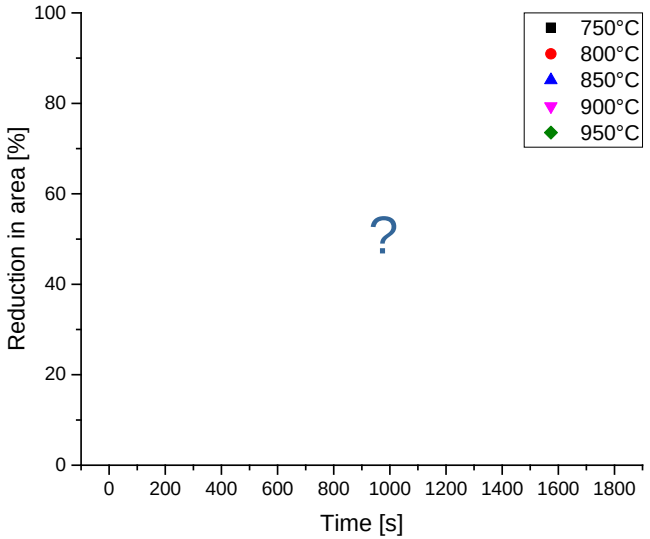
Ongoing work

- Temperature range 750 to 950°C
- Exposure time 5s to 1800s
- 180 samples for full setup (3 replicates)



Ongoing work

- Ductility measured as reduction in area
- Supplemented by microstructural characterization



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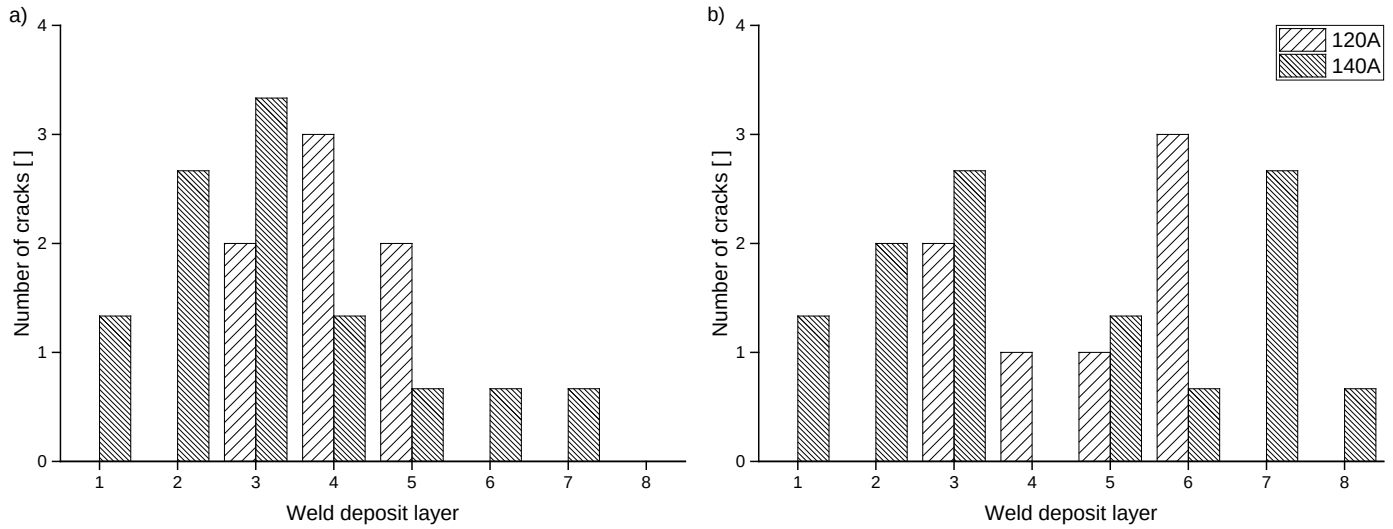
Project status

- **Repair welding of wrought Haynes® 282® using manual gas tungsten arc welding**
  - High heat input increased cracking by factor 1.5
  - No influence of base material microstructure on cracking response



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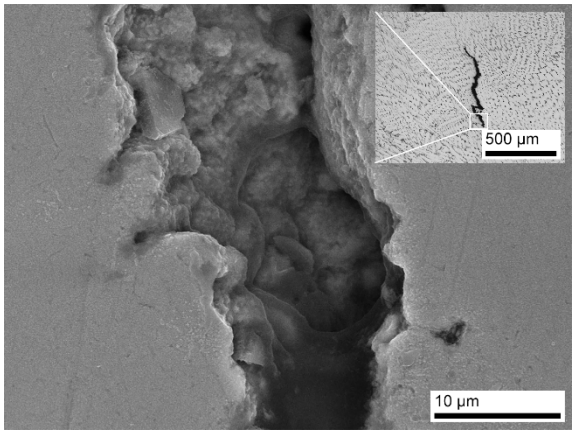
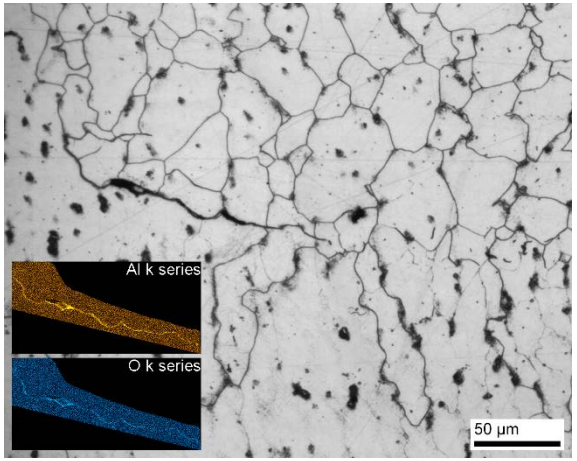
Project status

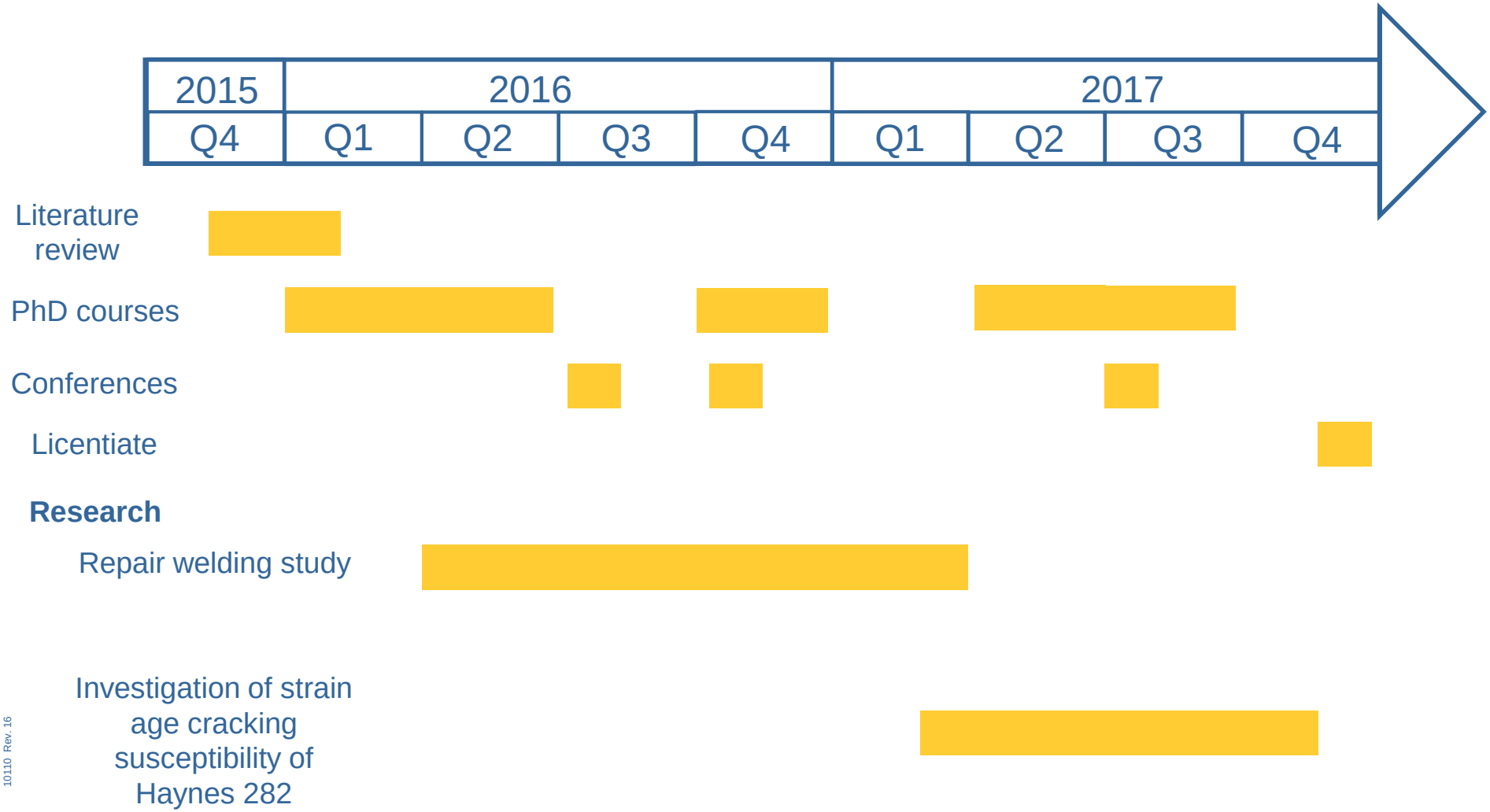
- No cracks in base metal HAZ
- Solidification cracks in FZ layers
- Voids appear to be solid state cracks in light optical microscopy
- EDS analysis shows that they are oxide layers present from welding process

- **Paper now submitted to Welding in the World**





Project status



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Hot Cracking in High Temperature Materials
KME 719

Sukhdeep Singh, Joel Andersson & Lars Nyborg

Aim of KME 719

- **Increase the knowledge concerning hot cracking of austenitic stainless steels and Ni-based superalloys:**
  - Generate weldability test data on materials relevant to the boiler industry
  - Recommend materials and parametres for improved weldability
  - Estabilish a testing methodology that can be used for assessing weldability with respect to hot cracking susceptibility

ATI® 718Plus™

- Different chemistry than 718
- Gamma prime strengthened
- Operating temperature max 700°C

Cast	Ni	Fe	Cr	Nb	Mo	Ti	Al	…
718Plus	Bal.	9.7	20.5	6.3	2.7	0.8	1.5	
718	52.98	Bal.	18.11	5.30	2.98	0.99	0.42	…

Composition in wt%

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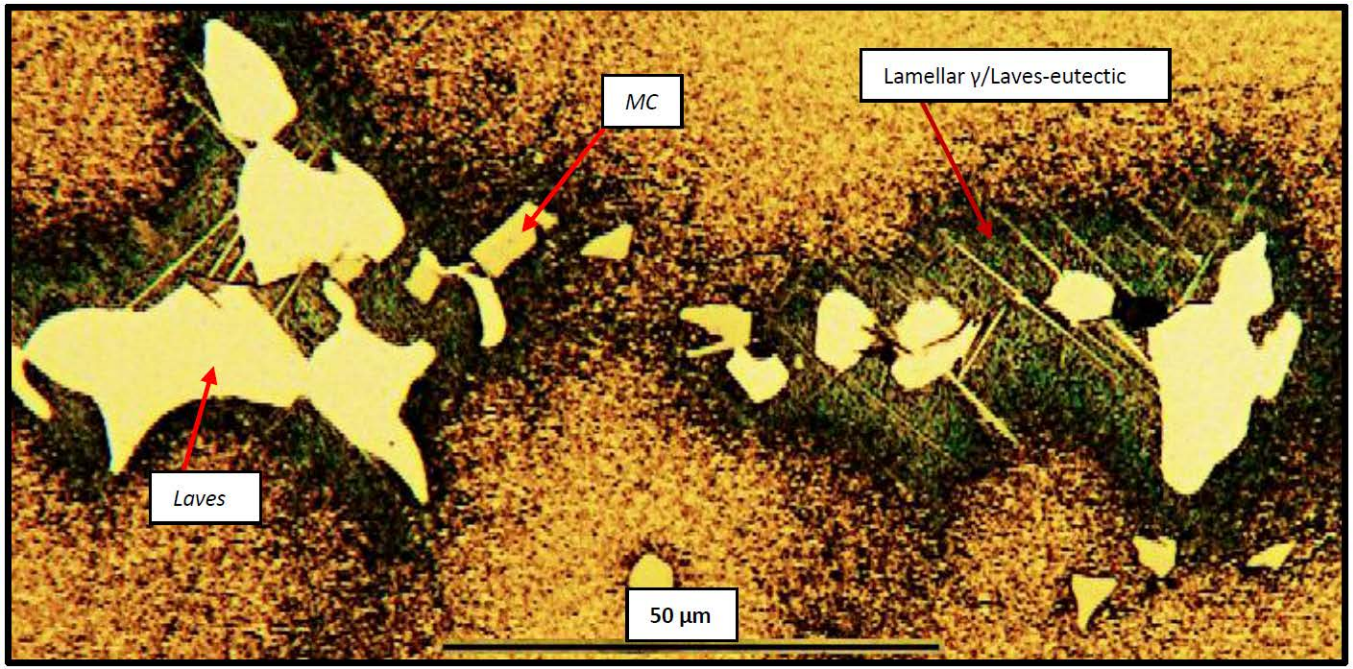
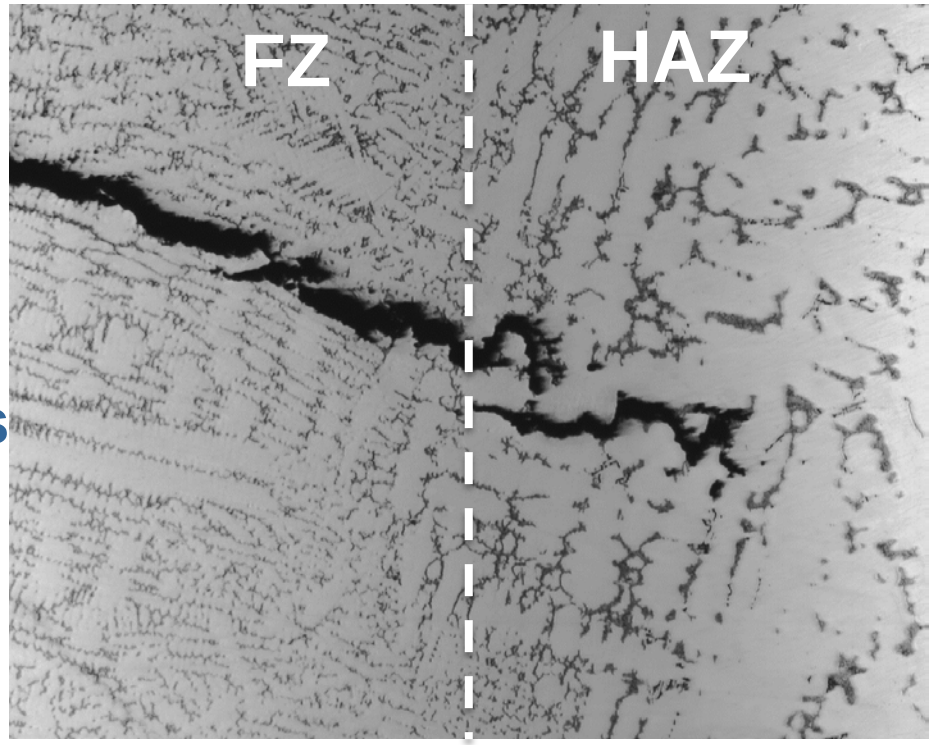
Cast ATI® 718 Plus™



Hot Cracking

$L \rightarrow \gamma + Laves$



Liquation of Laves eutectic

Crack susceptible microstructure + restraint

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Heat Treatments

1120°C/4h

1160°C/4h

1190°C/4h

As Cast

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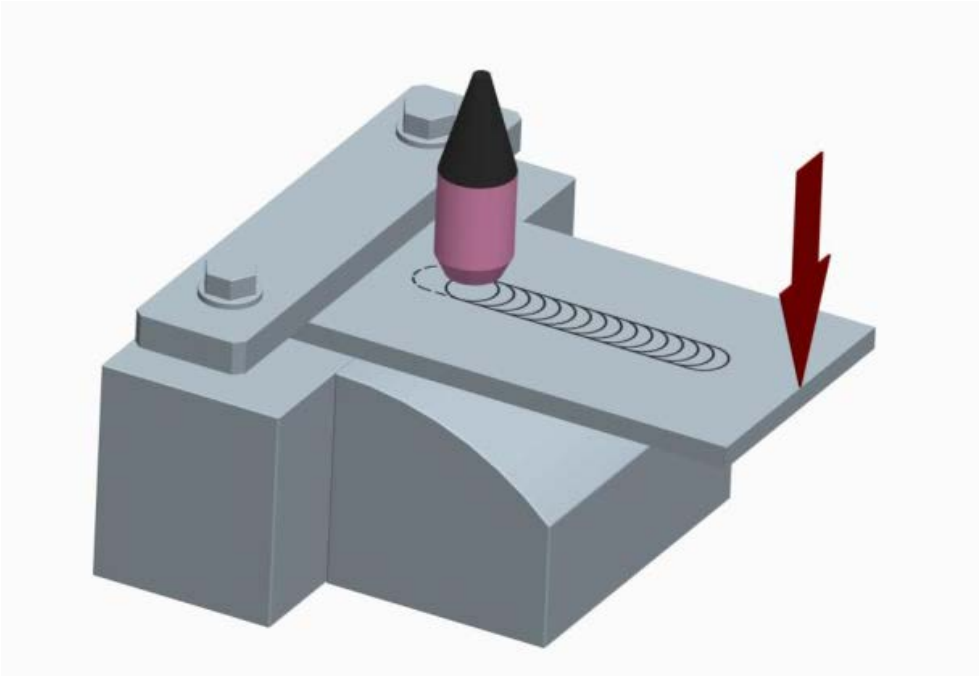
Varestraint Testing



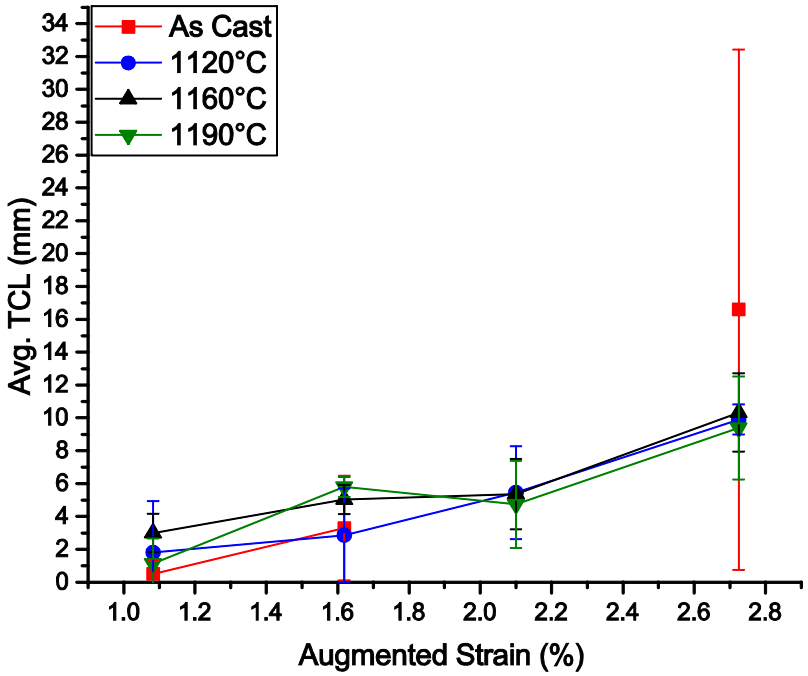
Parameters:

- Welding Speed = 1 mm/s
- Stroke rate = 10 mm/s
- Current = 70 A
- Ar gas flow = 15 l/min

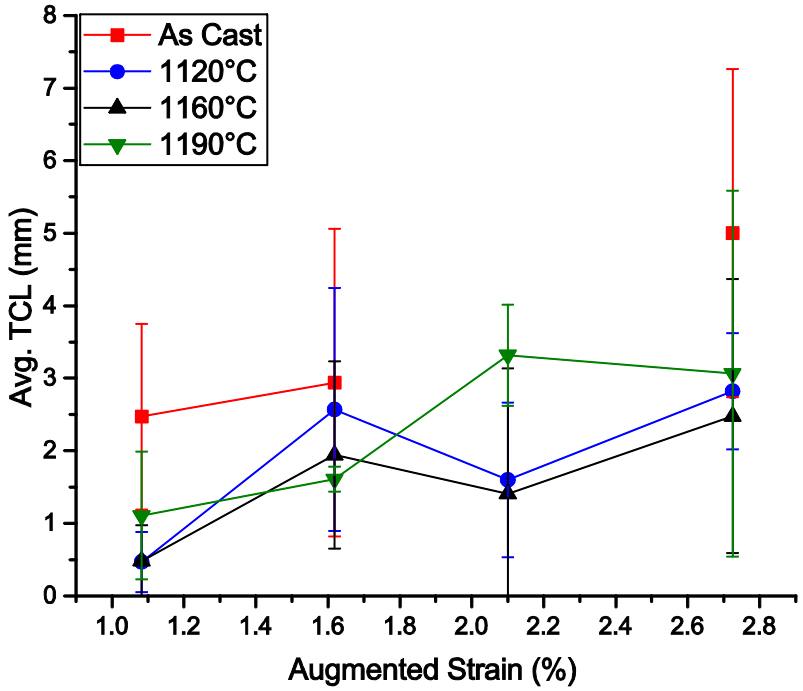
Radii: 60 ,75, 100, 150 (mm)

Results and Discussion

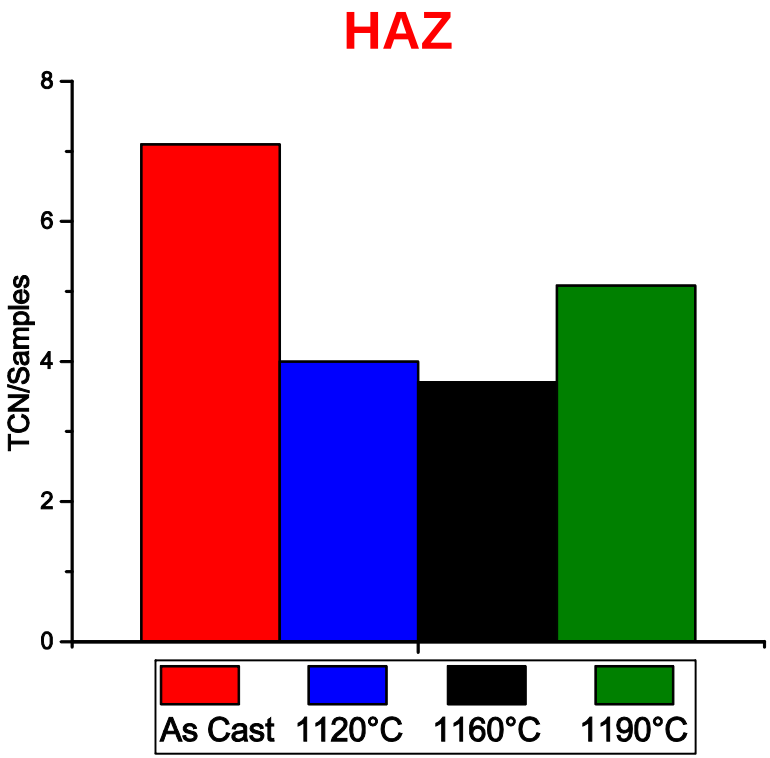
FZ

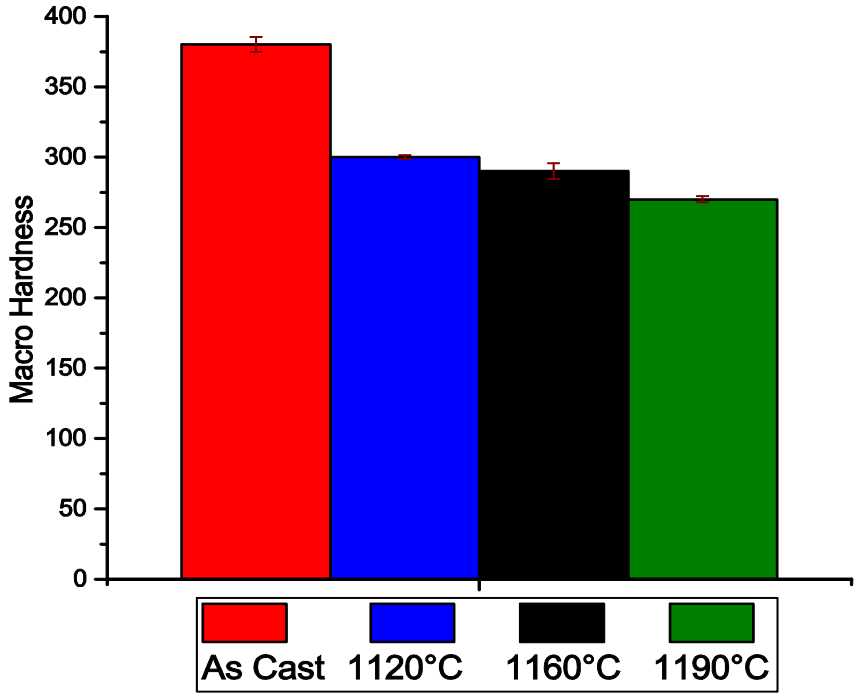


HAZ



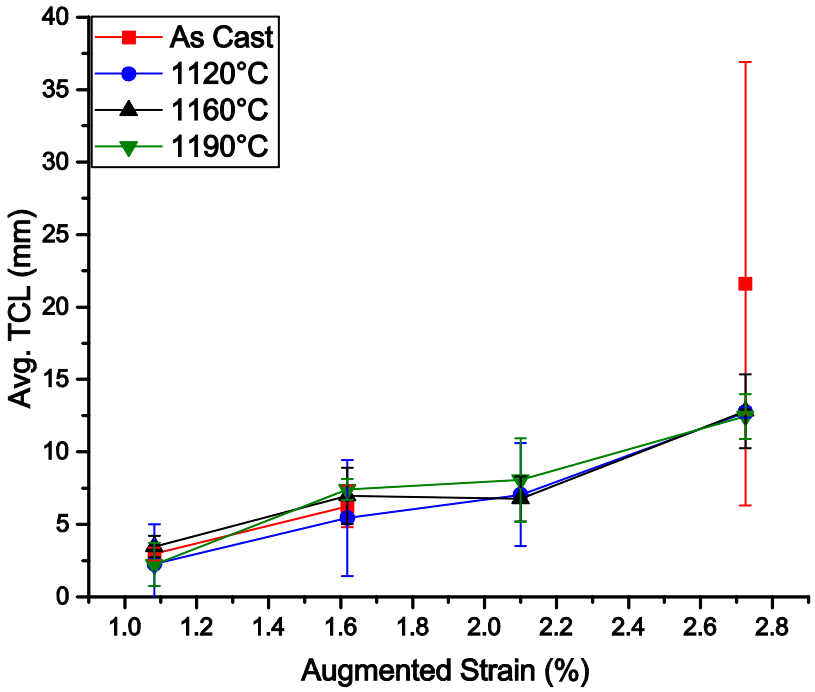
Results and Discussion



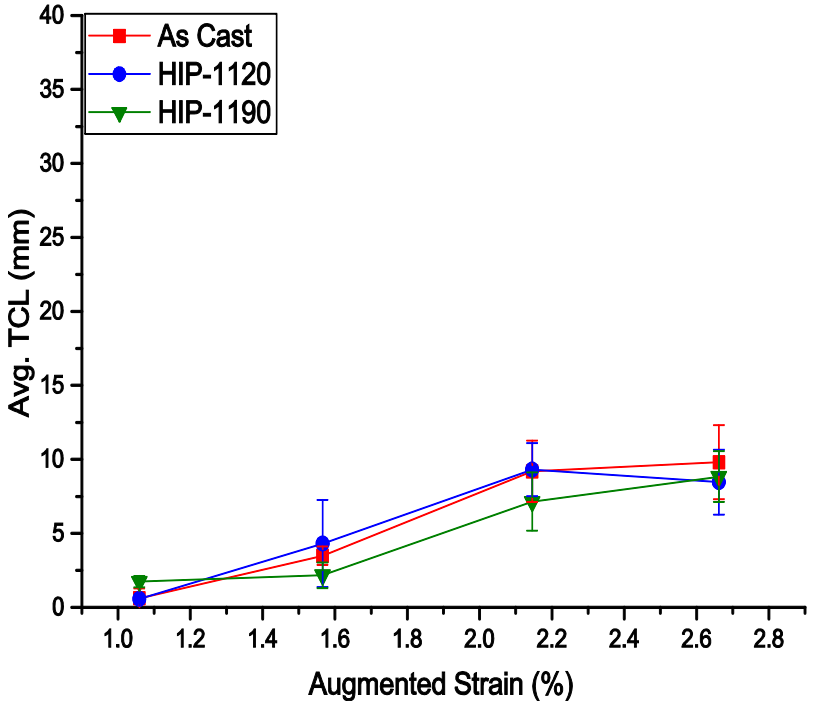


Results and Discussion

718Plus FZ



718 FZ



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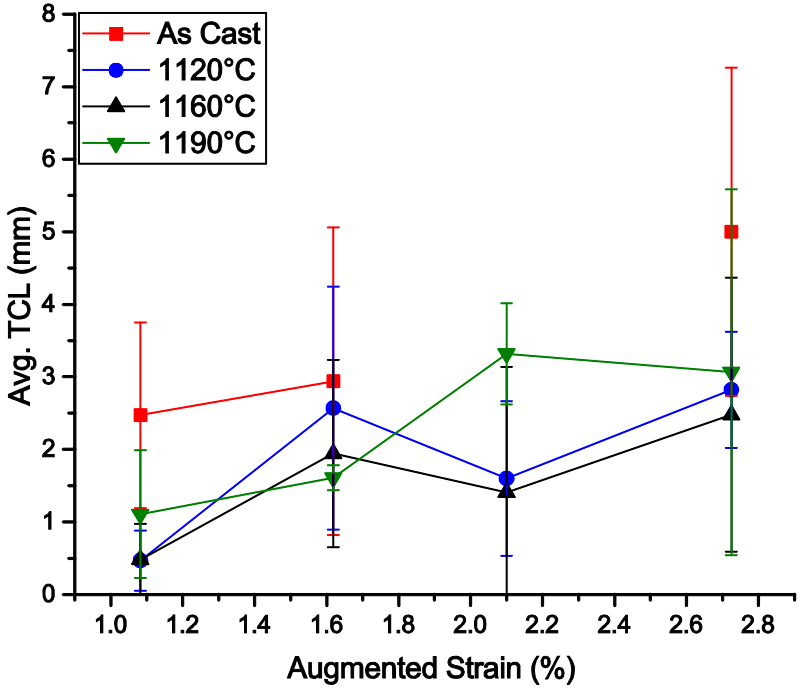
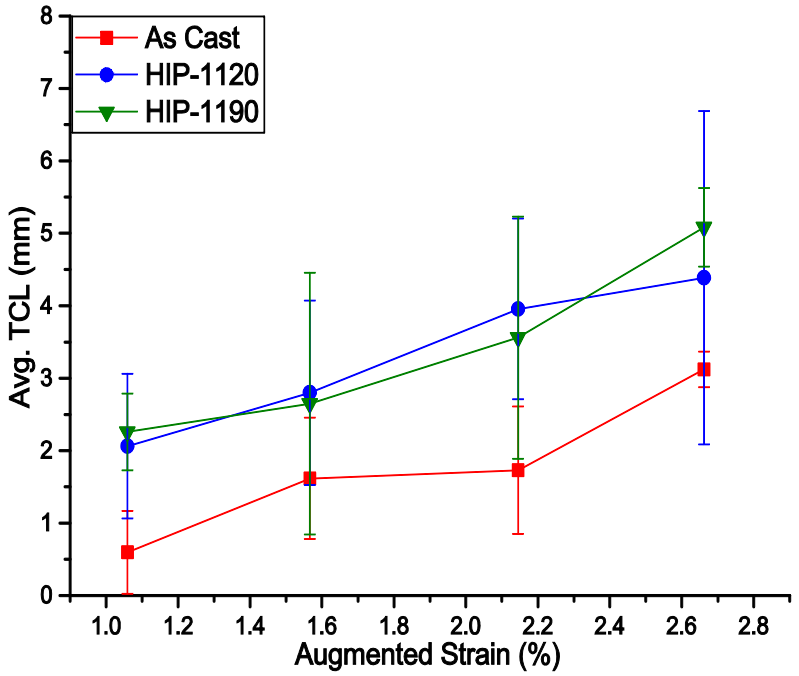
Results and Discussion

718Plus HAZ

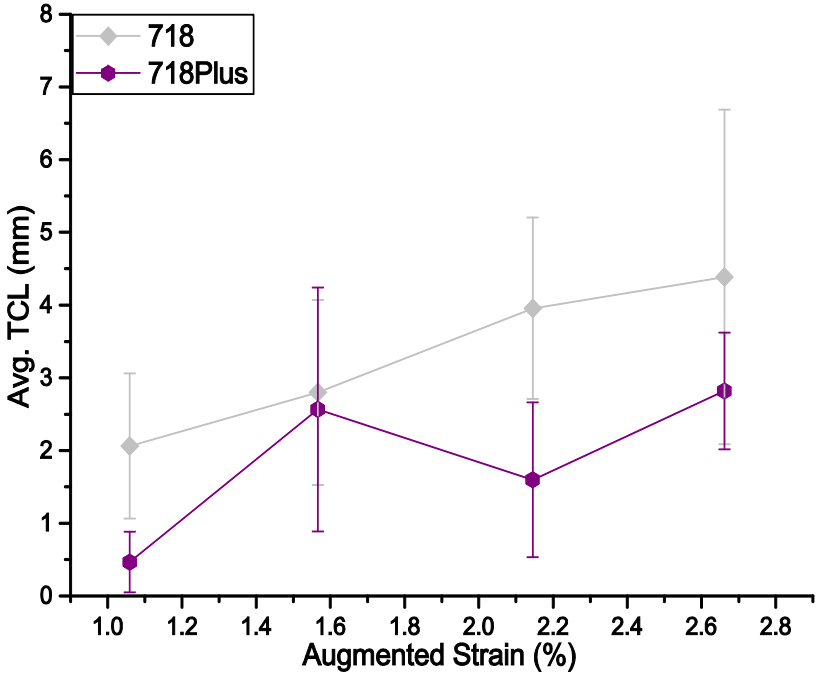


718 HAZ

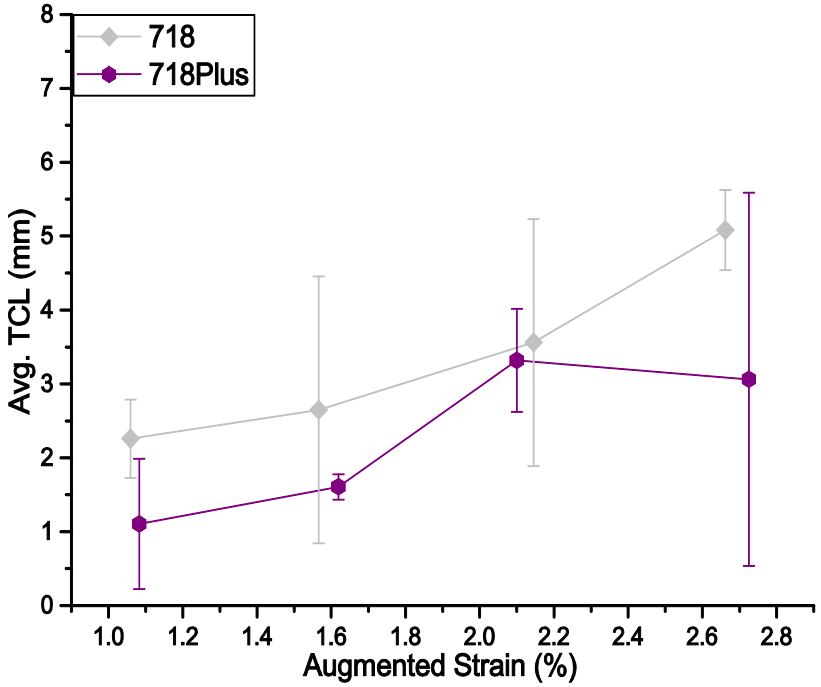


Results and Discussion

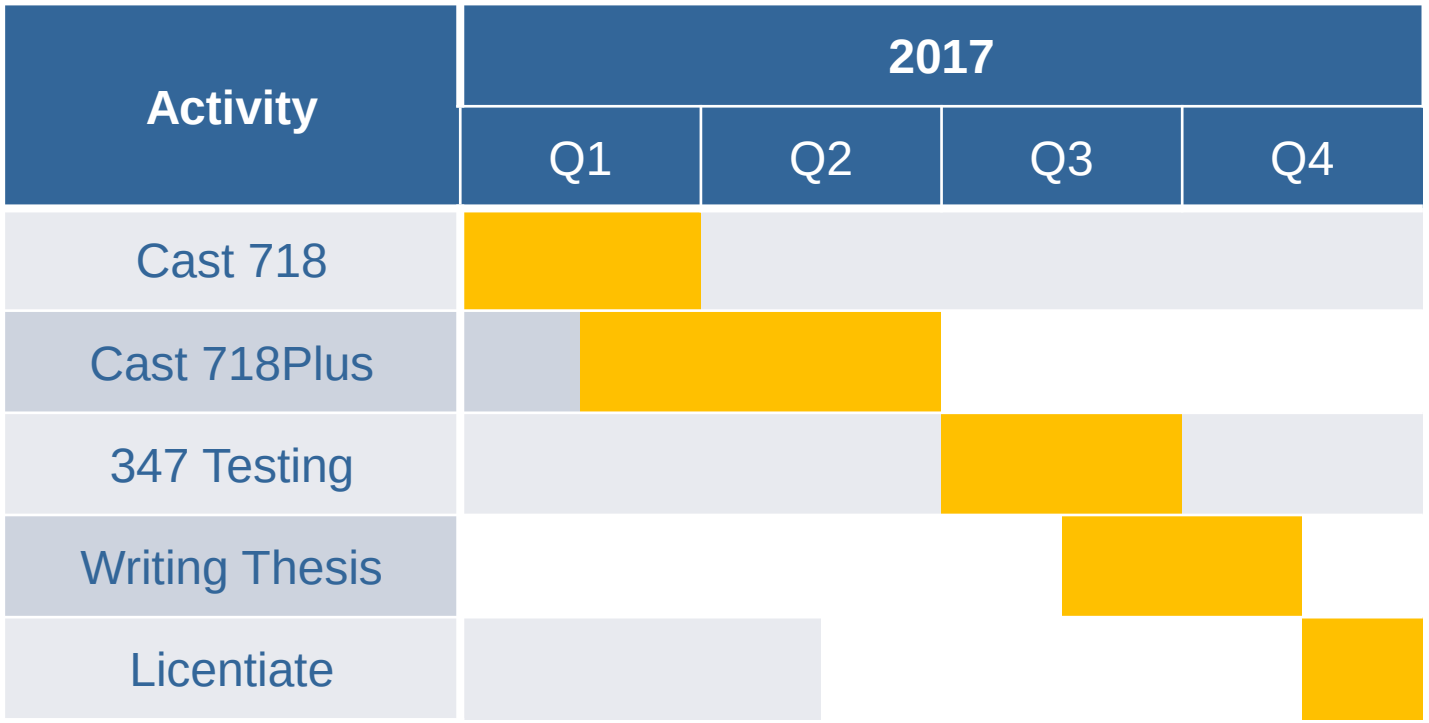
1120HAZ



1190HAZ



Ongoing work



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Thank you!