INL/MIS-22-66264-Revision-0

ASME Code Activities

March 2020

Ting-Leung Sham

Changing the World's Energy Future

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

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ASME Code Activities

GIF VHTR Materials PMB Meeting, Virtual
March 9, 2022

Advanced Reactor Technologies Program
Advanced Materials R&D

Sam Sham
Idaho National Laboratory

U.S. NRC Endorsement of ASME Section III, Division 5 - Status

- U.S. Nuclear Regulatory Commission (NRC) is currently assessing ASME Section III, Division 5 (2017 Edition) and accompanying Code Cases for endorsement
- Draft Regulatory Guide (DG-1380) and draft NUREG (2245) on the endorsement of Division 5 were issued and public comment phase completed
  - DG-1380 places conditions in the areas of general requirements, mechanical design, metallic materials allowable stresses, and graphite materials/design of Division 5
  - DG-1380 is a revision to Regulatory Guide 1.87, Revision 1, 1975 (which endorsed the 159X series of ASME Code Cases, with conditions)
- NRC staff is currently reviewing the low-temperature and elevated temperature Alloy 617 code cases for endorsement
  - Results of the review will be incorporated into DG-1380 and changes will be announced publicly
- The formal endorsement of Section III, Division 5 and accompanying code cases, with conditions, will be made through Regulatory Guide 1.87, Revision 2

ASME Code Activities on Advanced Manufacturing

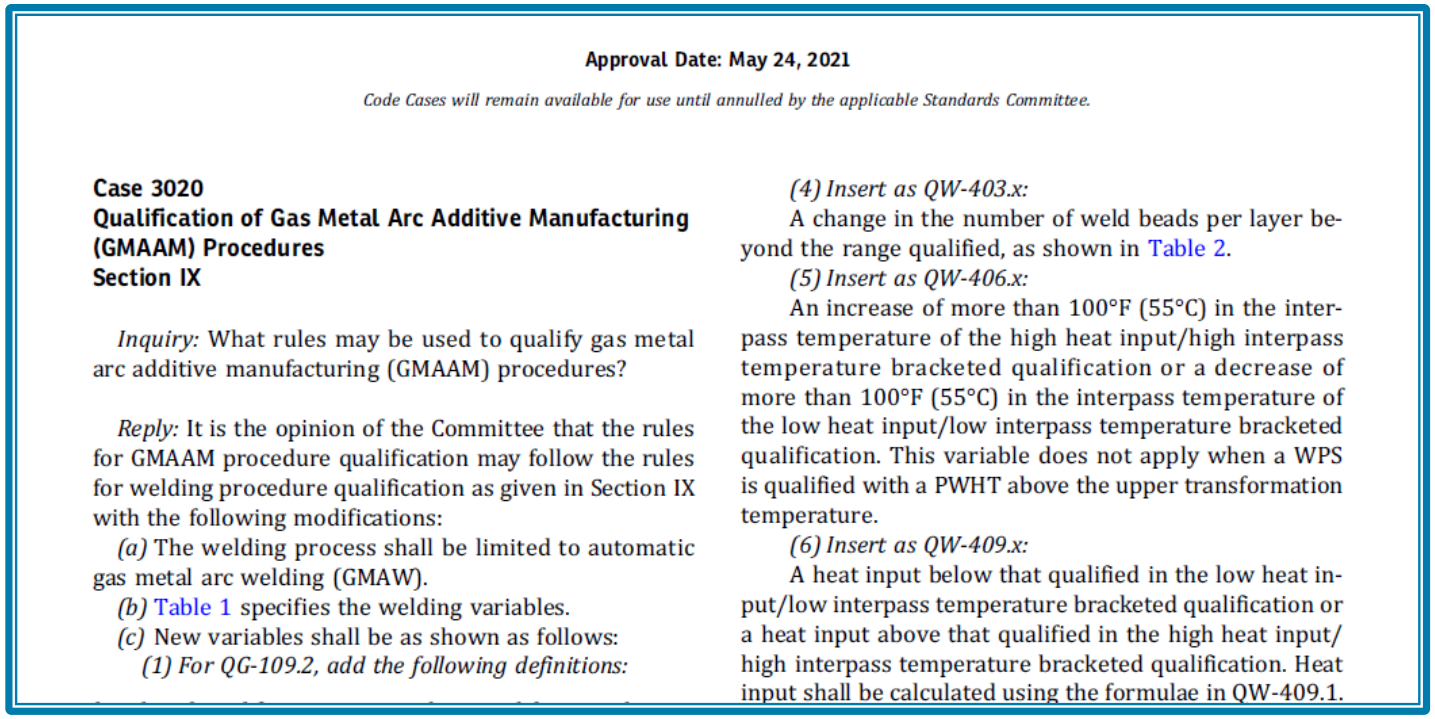
- Multiple codification efforts within ASME on advanced manufacturing (AM)
  - BPTCS/BNCS Special Committee On Use of Additive Manufacturing For Pressure Retaining Equipment
  - Section IX, Code Case 3020, procedural qualification of gas metal arc additive manufacturing (GMAAM)
  - Section III, Division 1, Task Group on Advanced Manufacturing
  - Section III, Division 5, Task Group on Division 5 AM Components

Special Committee On Use of Additive Manufacturing

- Special Committee was formed in August 2017 by Board on Nuclear Codes and Standards (BNCS) and Board on Pressure Technology Codes and Standards (BPTCS)
  - Charter: To develop a technical baseline to support development of a proposed BPTCS standard or guideline addressing the pressure integrity governing the construction of pressure retaining equipment by additive manufacturing processes. Construction, as used in this Charter, is limited to materials, design, fabrication, examination, inspection, and testing.
  - Current emphasis is on low temperature applications
- Issued a first report on the specific criteria addressing the Additive Manufacturing Powder Bed Fusion Process
  - Scope • Additive Manufacturing Specification • Materials • Thermal Treatment • Powder Requirements • Additive Manufacturing Design Requirements • Additive Manufacturing Procedure • Additive Manufacturing Procedure Qualification • Qualification Testing of Additive Manufactured Components • Production Build Cycles • Chemical Composition Testing • Mechanical Property Testing • Metallographic Evaluation • In-Process Monitoring • Quality Program • Records • Definitions • Referenced Standards
- Criteria on other Additive Manufacturing processes will follow

Section IX - Procedural Qualification of Gas Metal Arc Additive Manufacturing (GMAAM)

- Section IX issued Code Case 3020 on rules for GMAAM procedure qualification
- Provides an important pre-requisite for incorporating GMAAM in Section III, Division 1 for Class 1, 2 & 3 applications



Approval Date: May 24, 2021

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case 3020
Qualification of Gas Metal Arc Additive Manufacturing (GMAAM) Procedures
Section IX

Inquiry: What rules may be used to qualify gas metal arc additive manufacturing (GMAAM) procedures?

Reply: It is the opinion of the Committee that the rules for GMAAM procedure qualification may follow the rules for welding procedure qualification as given in Section IX with the following modifications:

(a) The welding process shall be limited to automatic gas metal arc welding (GMAW).

(b) Table 1 specifies the welding variables.

(c) New variables shall be as shown as follows:

(1) For QG-109.2, add the following definitions:

(4) Insert as QW-403.x:

A change in the number of weld beads per layer beyond the range qualified, as shown in Table 2.

(5) Insert as QW-406.x:

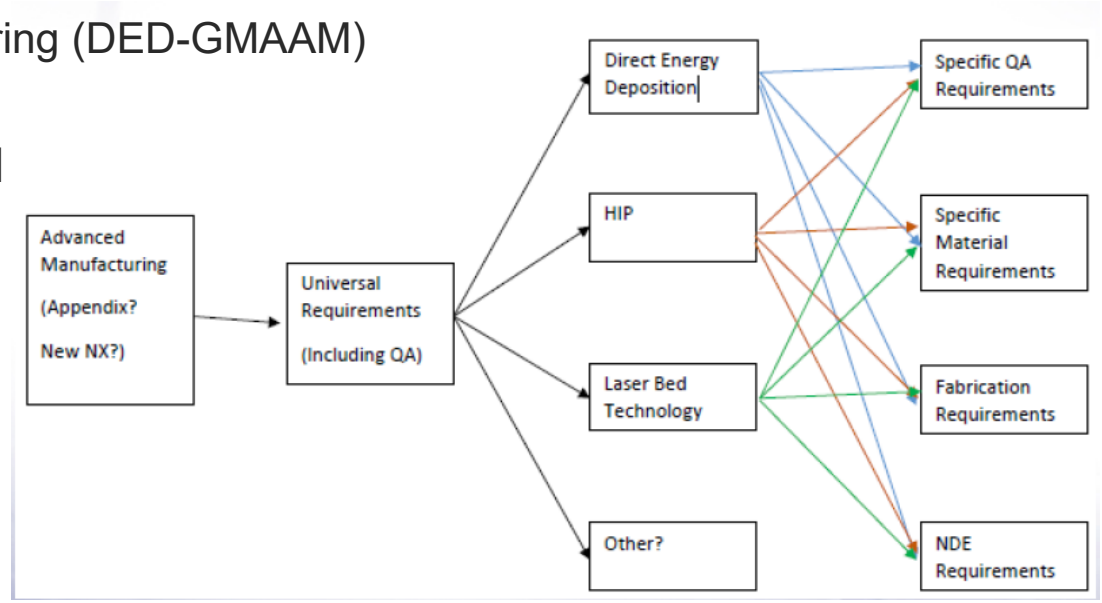
An increase of more than 100°F (55°C) in the interpass temperature of the high heat input/high interpass temperature bracketed qualification or a decrease of more than 100°F (55°C) in the interpass temperature of the low heat input/low interpass temperature bracketed qualification. This variable does not apply when a WPS is qualified with a PWHT above the upper transformation temperature.

(6) Insert as QW-409.x:

A heat input below that qualified in the low heat input/low interpass temperature bracketed qualification or a heat input above that qualified in the high heat input/high interpass temperature bracketed qualification. Heat input shall be calculated using the formulae in QW-409.1.

Section III, Division 1, Task Group on Advanced Manufacturing

- Formed by BPV III in January 2021
  - Charter - The Task Group on Advanced Manufacturing (AM) is responsible for developing, clarifying, and prescribing rules for the fabrication and stamping of items manufactured by techniques including: Powder Metallurgy / Hot Isostatic Pressing; Powder Bed-Additive Manufacturing; Direct Energy Deposition-Additive Manufacturing / Wire; Cold Spray Deposition/Cladding; and Diode Laser Cladding
- Three Process Specific Focus Groups formed: Quality Assurance • PM/HIP • DED-GMAAM
- AM processes targeted for 2023 and/or 2025 code editions
  - Powdered Metal/Hot Isostatic Pressing (PM/HIP)
  - Direct Energy Deposition Gas Metal Arc Additive Manufacturing (DED-GMAAM)
  - Laser Powdered Bed Fusion (LPBF)
- Philosophy for AM incorporation into Section III, Division 1
  - Section III, Article 2000 to support AM Product Form
  - Reference Mandatory Appendix for AM rules



Intended Structure for Incorporating New Division 1 AM Rules

- PM/HIP
  - Incorporation based upon approved Code Case N-834, ASTM A988/A988M-11 for UNS S31603 (316L)
  - Expanding scope to include additional alloys for future editions
- Directed Energy Deposition (DED)
  - Selected DED-GMAAM as the first DED process to be incorporated
  - Incorporation based upon approved Section IX Code Case 3020
  - GMAAM selected as it is an extension of current industry experience
  - Welds and weld metal build up technology with decades of demonstrated in-service experience

Section III, Task Group on Division 5 AM Components

- Charter - Fabrication of nuclear components for elevated temperature service using advanced manufacturing (AM) methods is of increasing interest from the vendor community. These methods can include, for example, hot isostatic pressing near net shape components from powder, powder bed fabrication, wire feed methods and diffusion bonding. This Task Group will determine appropriate approaches for qualifying materials processed by AM methods and specifying acceptance criteria for components produced by these methods. The goal of the Task Group is to develop Code Actions for incorporating AM materials and components in Division 5 for elevated temperature nuclear construction.
- Initial focus is on PM/HIP
  - Developed structure of PM-HIP low temperature and elevated temperature code cases
    - Low temperature code case will be similar to the Division 1 PM-HIP rules but for Division 5 applications
  - Developed a R&D roadmap on approach to qualifying PM HIP for Division 5 applications

DOE Effort - Procured 316H PM HIP bar

Chemistry , in wt.%

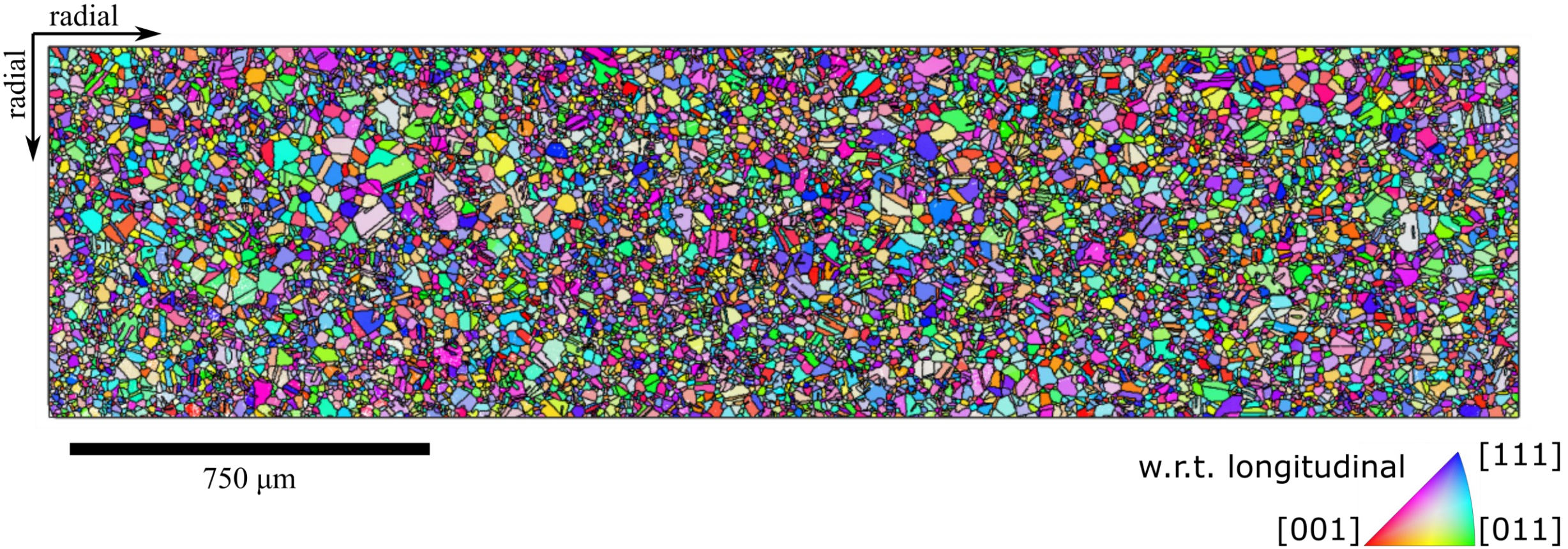
	C	Si	Mn	P	S	Cr	Ni	Mo	Al	Ti	N
Bar	0.040	0.17	0.21	0.002	0.003	16.44	11.95	2.48	0.007	0.005	0.147
Min	0.04					16.0	10.0	2.00			0.05
Max	0.1	0.75	2.00	0.045	0.030	18.0	14.0	3.00	0.03	0.04	

	B	Co	Cu	Nb	Ta	V	Fe	O	Ta+Co
Bar	0.0003	0.011	0.012	< 0.005	0.006	< 0.005	68.47	0.0202	0.017

Mechanical and microstructural properties

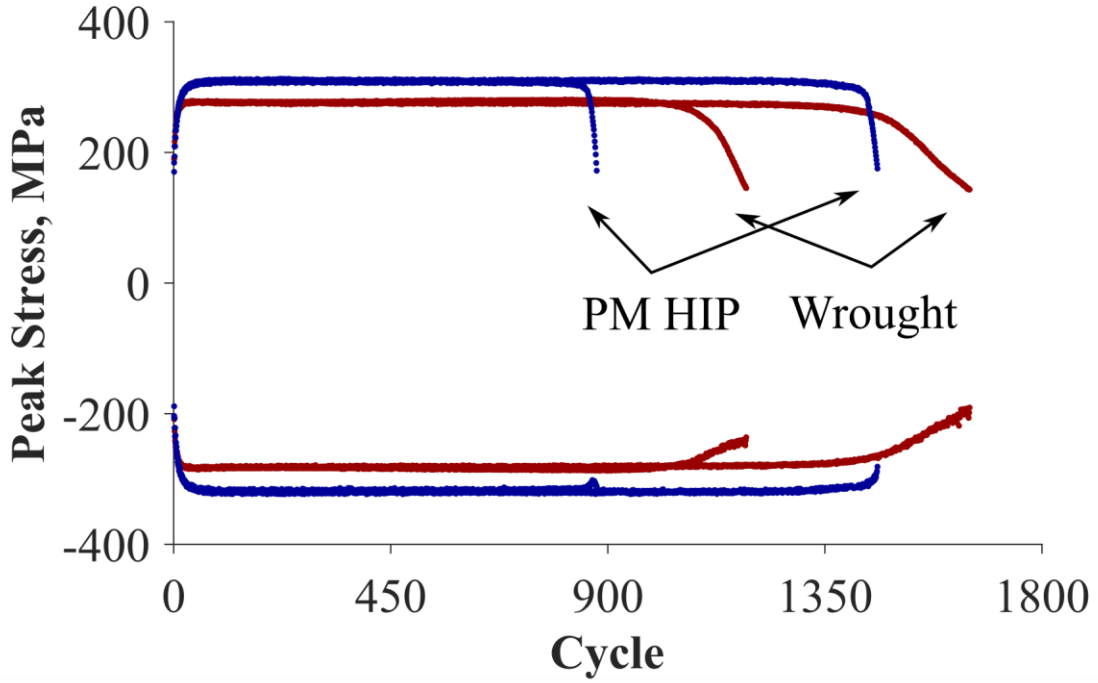
	Tensile Strength MPa	Yield Strength MPa	Elongation %	Hardness HRB	Grain size
Bar	671	370	50	89	7
Requirement	≥ 515	≥ 207	40	≤ 95	≤ 7

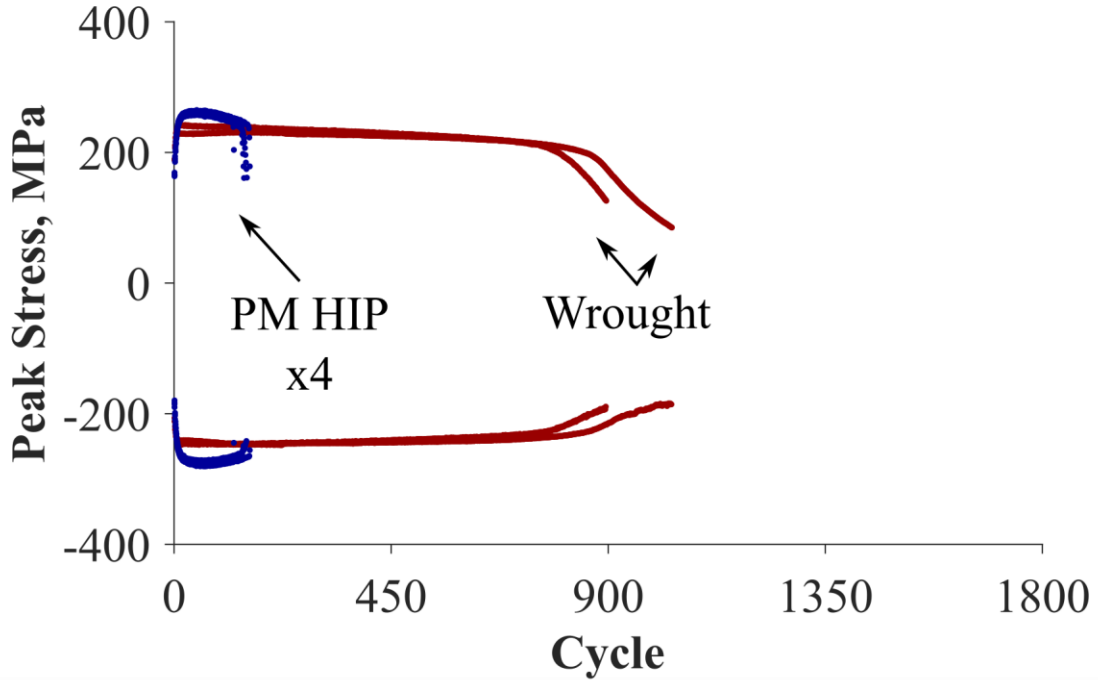
As-received microstructure



Elevated-Temperature Cyclic Properties – 316H

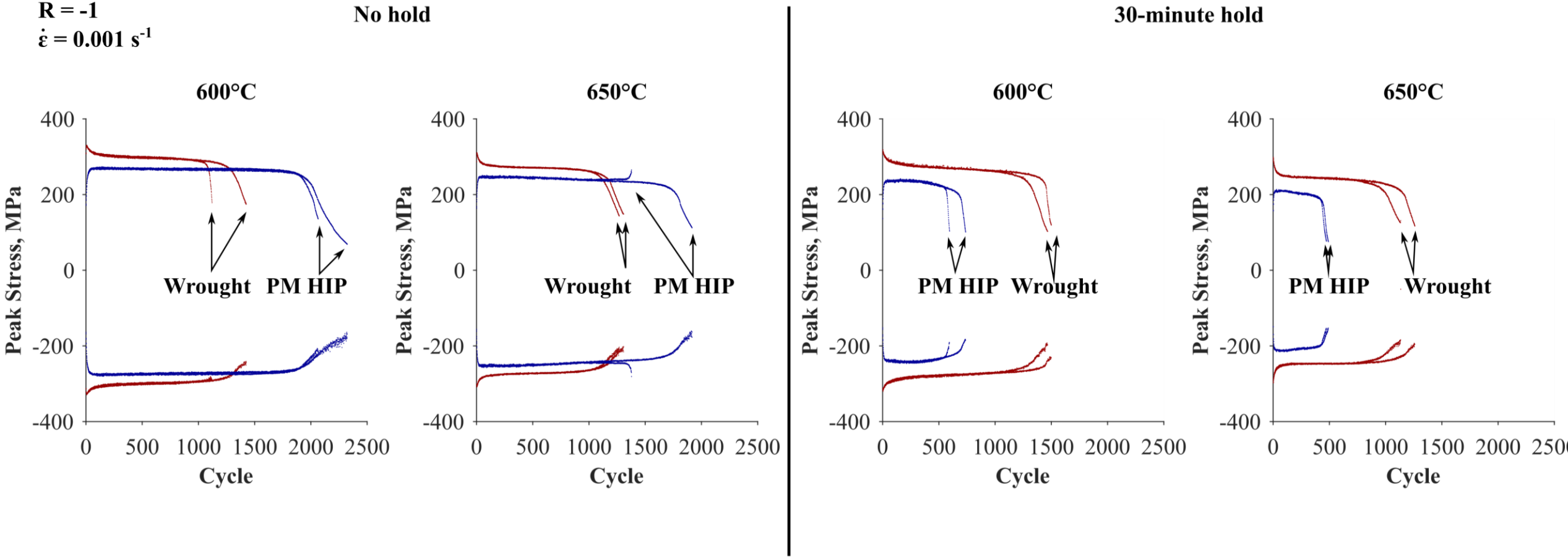
Alloy 316H
T = 650°C
Δε = 1%
R = -1
$\dot{\varepsilon}$ = 0.001 s^{-1}





Elevated-Temperature Cyclic Properties – 316L

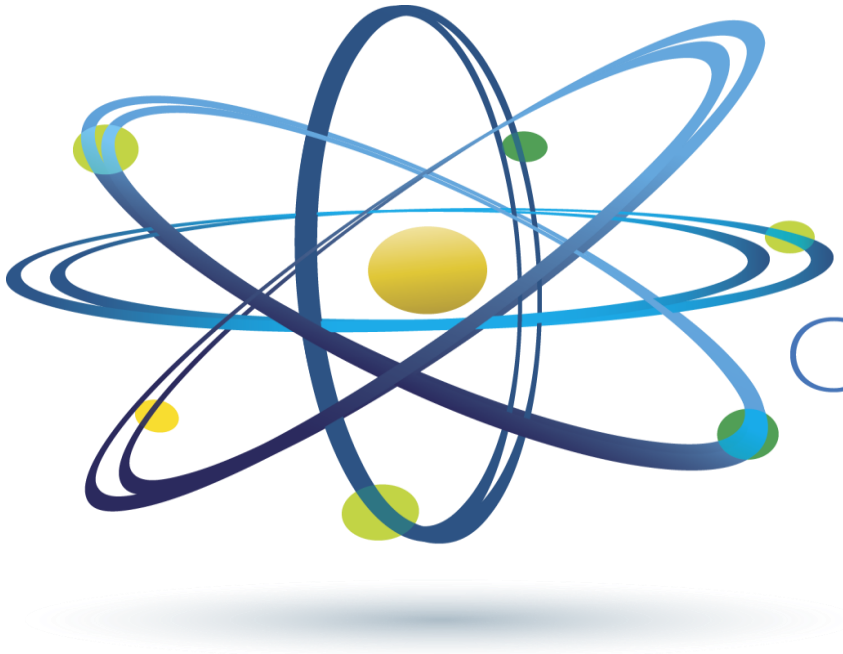
Alloy 316L
$\Delta\varepsilon$ = 1%
R = -1
$\dot{\varepsilon}$ = 0.001 s^{-1}



Summary of PM/HIP Results

- The 316H PM/HIP bar exceeded the minimum room-temperature tensile property requirements
- The elevated-temperature creep-fatigue properties of the 316H PM/HIP bar are reduced compared to the wrought material
- The mechanisms responsible for the observed behavior need to be identified
- Confirmatory testing of optimized material to demonstrate long term PM/HIP properties comparable to wrought 316H
- The UK Advanced Manufacturing Research Centre at the University of Sheffield will provide 316H PM/HIP materials (with lower powder oxygen contents) for INL to determine if the cyclic properties are improved

Questions



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