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GCR: Alloy 617 Crack Growth Testing Status

June 2022

Changing the World's Energy Future

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Idaho National Laboratory

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Advanced Reactor Technologies Program

Advanced Materials R&D Program Review

June 7 and 8, 2022

Joseph Bass

Idaho National Laboratory

Contributors

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Fiscal Year 2022 (FY-22) Work Packages

AT-22IN060405, Long-Term VHTR Material Qualification - INL

Motivation and Scope

This work focuses on methodologies for high-temperature flaw evaluations to support American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Section XI, Division 2, Reliability and Integrity Management (RIM) Programs.

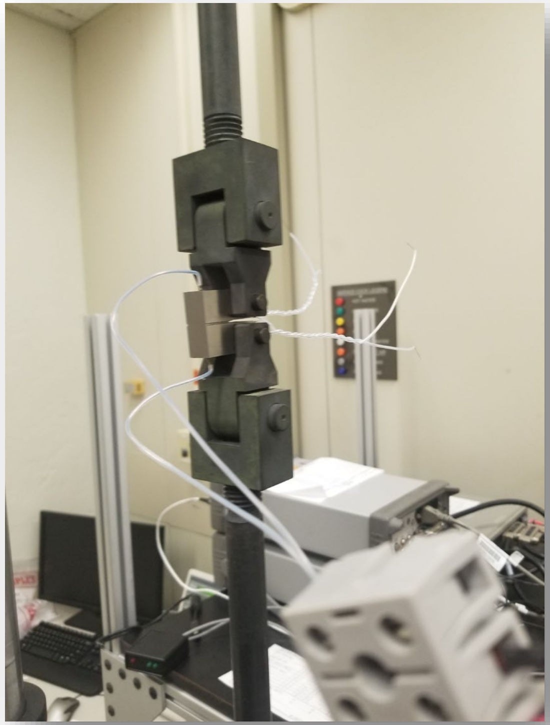
- Impurities in cooling gas can cause oxidation, carburization, and/or decarburization in Alloy 617 which can affect crack-growth rates.
- High-temperature crack-growth tests in air and in reactor-grade helium would provide data for establishing the crack-growth correlations in support of the ASME BPVC Section XI high-temperature flaw evaluation Code Case.
- Alloy 617 crack-growth testing is in progress to develop crack-growth data and to gain an understanding of the environmental effects (particularly impurities in the environment) on the crack-growth behavior of Alloy 617.
- Alloy 617 is qualified for the construction of ASME BPVC Section III, Division 5 components for a maximum service life and temperature of 100,000 hours and 950°C, respectively.

Background

Experimental Testing:

- A test frame with attached direction current potential drop (DCPD) system provides real time crack-growth information which allows for constant stress intensity testing (K) to be performed.
- Crack growth can be measured by the DCPD because as a crack propagates, the electrical resistance in a specimen increases and the resulting potential drop can can be correlated to the crack length.
- Crack-propagation data can provide insights on fatigue, creep-fatigue, and creep behavior which are necessary in a component safety analysis.

Loaded Specimen



Previous Work

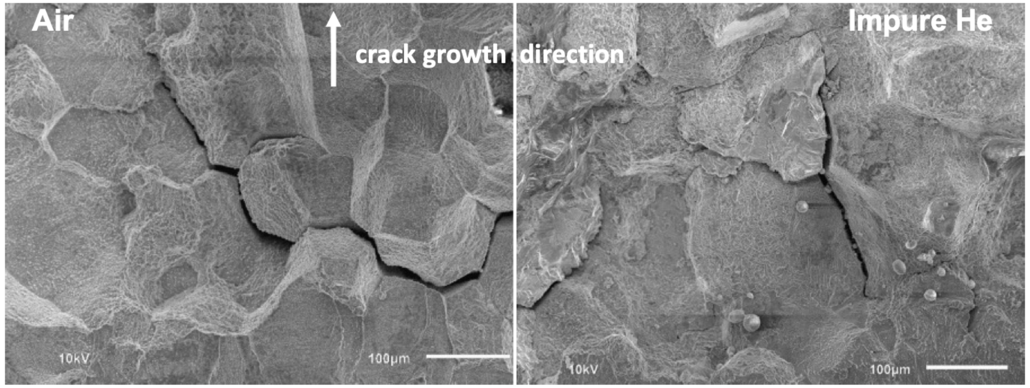
Previous Experimental Work:

- At INL, the effects of environment on crack-growth rates in Alloy 617 were investigated up at 650 and 800 °C.
- Constant stress intensity creep, creep-fatigue, and fatigue were run.
    - Variable load frequency fatigue tests
    - Variable hold times in creep-fatigue testing
- Carburized, aged, and unprocessed specimens were tested

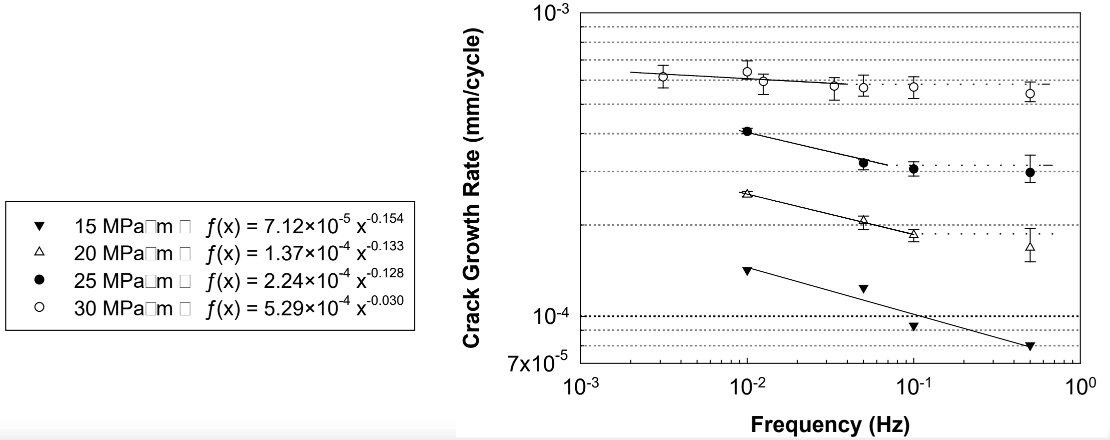
Previous Results:

- Intragranular cracking was observed for all testing excluding creep tests.
- It was theorized that oxidation was causing time-dependent behavior in the crack-growth rates.
- Aging did not have an appreciable effect on the crack growth rates while carburization showed increased crack growth.

Creep Crack Propagation[1]



Time Dependent Crack Growth Rates[1]



[1]Benz, Julian, et al. "Fatigue and Creep Crack Propagation behaviour of Alloy 617 in the Annealed and Aged Conditions ", Third International Workshop on Structural Materials for Innovative Nuclear Systems, Idaho National Laboratory, INL/CON-13-30214, October 2013.

Current Status

Most of the 2022 fiscal year (FY-22) has been spent completing necessary preparatory work including:

Acquiring Components:

- Alloy 617 compact-tension (CT) specimens (0.5T) have been machined.
- Laboratory equipment necessary to perform crack-growth testing in air using a DCPD to measure crack growth has been assembled.

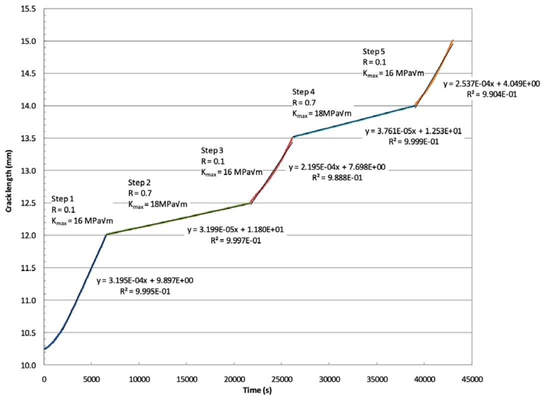
Crack Growth Validation Testing:

- A test plan developed in a previous study at INL was implemented.
- The results show good agreement with previous results for the same test plan.
- A discrepancy of approximately 5 percent was observed between the computed crack length from the DCPD and the optical crack measurements.

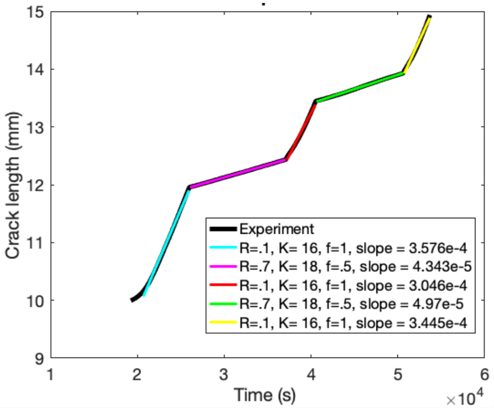
Alloy 617 CT Specimen

Validation Test Results

Previous Study[1]



This Work



[1]Wright, Richard, et al. "Initial Results on Characterization of Elevated Temperature Crack Growth of Alloy 617", Engineering Calculation and Analysis Report, ECAR No.: ECAR-1539, Idaho National Laboratory, 5/25/2011.

Future Work

Planned Testing

- A DCPD system will monitor crack growth due to fatigue loading with constant stress intensity at temperatures up to 1000°C in air and impure-helium environments.
  - A second test frame will be used to conduced environment controlled (impure helium) testing.
  - Environmental control equipment including a gas chromatograph currently resides in the laboratory, but work is needed to complete and confirm functionality of the environmental control system.
- Variation in temperature as well as loading frequency will help answer questions associated with the effect of environment on crack-growth rates.

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