New Mechanistic Models of Creep-Fatigue Crack Growth Interactions for Advanced High Temperature Reactor Components

PI: Jamie Kruzic, Associate Professor, Oregon State University

Collaborators: Thomas Siegmund, Professor, & Vikas Tomar, Associate Professor, Purdue University

Program: RCD&D: Creep Fatigue

ABSTRACT:

Objectives and Potential Impact: Our objective is to create and validate a robust, multi-scale, mechanism-based model that quantitatively predicts creep-fatigue crack growth (CFCG) and failure in Ni-based reactor alloys. Further, our objective is also to the collect the needed model parameters for a technologically relevant nuclear reactor alloy (Alloy 617) and use that alloy for model validation.

Description: The following are the tasks that will be addressed by the investigators.

1) Model development and refinement: The model will be developed and refined at Purdue University where the Co-PI#1 (Siegmund) has extensive expertise in the development of strain gradient irreversible cohesive zone models for the prediction of fatigue crack growth rates.
2) Measurement of model parameters for a relevant nuclear reactor alloy (Alloy 617): The PI (Kruzic) at Oregon State University has extensive facilities and expertise for high temperature fatigue and creep crack growth experiments, low cycle fatigue experiments, and creep deformation experiments needed to measure the cohesive zone model parameters. The Co-PI#2 (Tomar) at Purdue University possesses extensive expertise and high temperature nano- and micro-indentation facilities for measurement of the needed strain gradient plasticity parameters.
3) Validation of predictive capabilities of the model: The PI (Kruzic) at Oregon State University has extensive facilities and expertise for high temperature creep-fatigue crack growth experiments to examine the transferability of the model to arbitrary cyclic frequencies and dwell times.

To complete this project, the following methods and unique capabilities of the investigators will be in use:

1) At Oregon State University, the PI Kruzic has extensive experience in conducting experimental work in fatigue and fracture in various environments and at various temperatures including elevated temperature fatigue crack growth studies up to 1300 °C. For the OSU effort, $340,790 will be used over the three year period of performance.
2) At Purdue University the Co-PI#1 Siegmund as developed relevant code elements for irreversible cohesive zone models and strain gradient plasticity as add-ons for the commercial FE code ABAQUS. Also at Purdue University, the Co-PI#2 (Tomar) as unique laboratory facilities for high temperature nanoindentation up to 1000 °C. For the combined Purdue effort, $450,000 will be used over the three year period of performance.

The potential impact of this project is that a successful model can be embedded into standard finite element software as an analysis tool for reactor designers and greatly improve their capability to design against creep fatigue failures for all reactor alloys in the long term, while in the short term the model parameters will be made available for a technologically important Ni-based alloy used in nuclear reactors (Alloy 617).