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Grantee: The Ohio State University
Title of Grant: ICME Approach for Materials and Process Optimization to Prevent Ductility-Dip Cracking in Welds of Ni-based Alloys for Nuclear Application
Period of Performance: 11/15/2022-11/142025 (FY22 Notice of Funding Opportunity NOFO)

Executive Summary

This research will develop and demonstrate an innovative integrated computational materials engineering (ICME) approach for materials-related welding process optimization that mitigates ductility dip cracking (DDC) in welded structures of Ni-based alloys for nuclear applications. The project addresses the NRC programmatic mission objectives related to aging/degradation of plant components and advanced materials, manufacturing, and construction for nuclear builds. The proposed ICME approach utilizes the concepts of mitigating DDC by refining the weld metal microstructure through recrystallization and promoting grain boundary tortuosity through carbide precipitation. The effect of recrystallization is accounted for by finite element analysis (FEA) modeling of the local thermo-mechanical behavior in multipass welds. The carbides behavior is quantified utilizing thermodynamic and kinetic models. A specially developed computational design of experiment (CDoE) software module combines the FEA and carbide behavior models and performs DoE simulations with varying process parameters to identify optimal welding conditions for mitigating DDC. The ICME approach will be validated and demonstrated by manufacturing and characterization of highly restrained Ni-based welds, using optimized process parameters for avoiding DDC, and by computational modeling of existing welds with DDC. This ICME approach will provide a powerful tool for materials selection and welding process optimization to prevent DDC and save millions of dollars in repair and rework costs for aging reactor maintenance and new reactor construction. The primary expected outcome of this research is the increased safety and security of nuclear power facilities due to better avoidance of DDC, a cracking phenomenon which represents a vulnerability both in terms of radioactive containment and affordability in the construction and maintenance of nuclear reactors.

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Presentations and Publications

The list of publications was submitted with the final report after grant expiration.

1.
2. Alexandrov B.T., A. Singh, S.J. Luther, Y. Luo, M. Pacenta, M. Mills. 2025. New Developments in Studying Ductility Dip Cracking in Welds of Austenitic Alloys. Submitted to: *Proceedings, 5th Cracking Phenomena in Welding and Additive Manufacturing Conference*, Springer, 2025.
3. Singh A., B.T. Alexandrov, M. Mills, S. Luther, S. McCracken, J. Tatman. 2024. Quantification of Dynamic Recrystallization and Its Relation to Imposed Mechanical Energy and Ductility Dip Cracking in High Chromium Nickel Alloy Groove Welds. Proceedings, *10th International Conference Advances in Materials, Manufacturing & Repair for Power Plants*. ASM International, 2024.

Conference presentations

4. Welsh J.G., Development of Gleeble™-Based Test for Evaluation of DDC Susceptibility in Austenitic Alloys. 2025 *AWS Professional Program and Poster Session Conference,* Chicago, October 9, 2025.
5. Alexandrov B.T., A. Singh, S.J. Luther, Y. Luo, M. Pacenta, M. Mills 2025. New Developments in Studying Ductility Dip Cracking in Welds of Austenitic Alloys. **Keynote**. *5th Cracking Phenomena in Welding and Additive Manufacturing Conference*, Trollhättan, March 14, 2025.
6. Singh A., B.T. Alexandrov, M. Mills, S. Luther, S. McCracken, J. Tatman. 2025. Quantification of Dynamic Recrystallization and Its Relation to Imposed Mechanical Energy and Ductility Dip Cracking in High Chromium Nickel Alloy Groove Welds. *10th International Conference Advances in Materials, Manufacturing & Repair for Power Plants*. ASM International, Palm Springs, CA, February 25, 2025.
7. Alexandrov B.T. 2024. Weldability and Service Performance Evaluation of Welds in Advanced Alloys. **Keynote.** *FABTECH 2024. AWS Professional Program, Orlando, FL, October 16, 2024.*

Patents

N/A