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Engineering & Scientific Consulting

# Connor Slone, Ph.D., P.E.


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## Professional Profile

Dr. Slone specializes in solving complex problems related to materials science, metallurgy, fracture/fractography, failure analysis, and failure prevention. As a Licensed Professional Metallurgical Engineer, he assists clients with components and processes across a wide range of industries including power and utilities, oil and gas, industrial machinery and equipment, building and construction, and consumer products, among others.

While at Exponent, Dr. Slone has worked on many projects ranging from direct-cause failure analyses of single components to large, multidisciplinary investigations of integrated systems. He has leveraged his expertise to help clients understand or solve problems related to material and manufacturing issues, time-dependent material damage or degradation (including fatigue, corrosion, environmentally assisted cracking, and hydrogen embrittlement), or component overload. A common theme throughout his work is understanding the interplay between engineering design, manufacturing, metallurgical fundamentals, and component/system operating environments. Dr. Slone has extensive experience with optical and scanning electron microscopy, fractography, metallurgical and chemical analyses, computed tomography (CT), and mechanical testing techniques across a wide range of temperatures and loading modalities.

Dr. Slone has also supported and managed interdisciplinary project teams in many domestic litigation and international arbitration cases.

Prior to joining Exponent, Dr. Slone was a National Science Foundation Graduate Research Fellow at The Ohio State University. His doctoral thesis focused on the influence of composition and processing on the mechanical response of high entropy alloys. This work included computationally-screened alloy design via calculation of phase diagram (CALPHAD) techniques; thermo-mechanical processing of new alloys; mechanical assessment, including hardness measurement, rate-controlled tensile testing, and high-temperature creep testing; and analysis with electron-microscopy-based techniques such as energy dispersive X-ray spectroscopy (EDS), electron backscatter diffraction (EBSD), and electron channeling contrast imaging (ECCI).

In addition to his industry and research experience, Dr. Slone has also served as a teaching assistant for undergraduate and graduate materials science courses and led a practical laboratory course in scanning electron microscopy (SEM) methods. .

## Academic Credentials & Professional Honors

Ph.D., Materials Science and Engineering, The Ohio State University, 2019

B.S., Materials Science and Engineering, The Ohio State University, 2014

National Science Foundation Graduate Research Fellowship, 2015

## Professional Affiliations

ASM International (member)

American Association for the Advancement of Science (member)

## Publications

Stewart JR, Ganot GS, Slone CE, James BA, Roepke CT. Fractography of Weldments. ASM Metals Handbook Volume 12. 2024; 441 – 449

Slone C, Mostaed E, Cline C, Kaplowitz D ,Ganot G, James B, Aguiar D. Copper Contamination Cracking in a Pipeline Repair Weld. Journal of Failure Analysis and Prevention, February 2024.

J.J. Rindler, C.E. Slone, E.D. Herderick, M.J. Mills, A.J. Ramirez, "Investigation on the Potential Effects of Laser Stitching and Subsequent Heat Treatment on the Microstructure and Mechanical Properties of Nickel Alloy 718 Produced Via Laser Powder Bed Fusion (L-PBF)", Additive Manufacturing (57), 102906, 2022.

M. Heczko, V. Mazanova, C.E. Slone, M. Shih, E.P. George, M. Ghazisaeidi, M.J. Mills, "Role of deformation twinning in fatigue of CrCoNi medium-entropy alloy at room temperature", Scripta Materialia (202), 113985, 2021.

C.E. Slone, B. Barnett, B. Georgin, A. Vivek, E.P. George, G.S. Daehn, M.J. Mills, "Solid state welding of amedium-entropy CrCoNi with heterogeneous, partially recrystallized microstructures", Materials Science and Engineering: A (818), 141425, 2021.

J. Miao, C.E. Slone, S. Dasari, M. Ghazisaeidi, R. Banerjee, E.P. George, M.J. Mills, "Ordering effects on deformation substructures and strain hardening behavior of a CrCoNi based medium entropy alloy", Acta Materialia (210), 116829, 2021.

C.E. Slone, C.R. LaRosa, C.H. Zenk, E.P. George, M. Ghazisaeidi, M.J. Mills, "Deactivating deformation twinning in medium-entropy CrCoNi with small additions of aluminum and titanium", Scripta Materialia (178), 295-300, 2020.

C.E. Slone, E.P. George, M.J. Mills, "Elevated temperature microstructure evolution of a medium-entropy CrCoNi superalloy containing Al, Ti", Journal of Alloys and Compounds (817), 152777, 2020.

C.E. Slone, J. Miao, E.P. George, M.J. Mills, "Achieving ultra-high strength and ductility in equiatomic CrCoNi with partially recrystallized microstructures", Acta Materialia (165), 496-507, 2019.

C.E. Slone, S. Chakraborty, M.J. Mills, S.R. Niezgoda, "Influence of deformation induced nanoscale twinning FCC-HCP transformation on hardening and texture development in medium-entropy CrCoNi alloy", Acta Materialia (158), 38-52, 2018.

C.E. Slone, J. Miao, M.J. Mills, "Ultra-high strength and ductility from rolling and annealing of a Ni-Cr-Co superalloy", Scripta Materialia (155), 94-98, 2018.

J. Miao, C.E. Slone, T.M. Smith, C. Niu, H. Bei, M. Ghazisaedi, G.M. Pharr, M.J. Mills, "The evolution of the deformation substructure in a Ni-Co-Cr equiatomic solid solution alloy", Acta Materialia (132), 35-48, 2017.

R.C. Kramb, P.R. Buskohl, C.E. Slone, M.L. Smith, R.A. Vaia, “Autonomic composite hydrogels by reactive printing: materials and oscillatory response”, Soft Matter (9), 1329-1336, 2014.

M.L. Smith, C.E. Slone, K. Heitfeld, R.A. Vaia, "Designed Autonomic Motion in Heterogeneous Belousov-Zhabotinsky (BZ)-Gelatin Composites by Synchronicity," Advanced Functional Materials (23), 2835-2842, 2013.

M.L. Smith, K. Heitfeld, C.E. Slone, R.A. Vaia, "Autonomic hydrogels through postfunctionalization of gelatin", Chemistry of Materials (15), 3074-3080, 2012.

**Presentations**

C.E. Slone, J. Miao, E.P. George, M.J. Mills, "Ultra-high strength and anomalous hardening in FCC Medium / High Entropy Alloys", TMS 2018, March 2019, San Antonio, TX.

C.E. Slone, J. Miao, E.P. George, M.J. Mills, "Enhanced strength and ductility in Ni-Co-Cr alloys through cold work and annealing", 18th International Conference on the Strength of Materials, July 2018, Columbus, OH.

C.E. Slone, S. Chakraborty, S.R. Niezgoda, M.J. Mills, "Experimental and computational analysis of deformation in solid solution and precipitation strengthened Ni-Cr-Co alloys", TMS 2018, March 2018, Phoenix, AZ.

C.E. Slone, M.J. Mills, "Elevated temperature tensile and creep behavior of equiatomic NiCrCo", TMS 2018, March 2018, Phoenix, AZ.

C.E. Slone, M.J. Mills, "Analysis of strain localization during creep of a polycrystalline superalloy using SEM-DIC", TMS 2017, February 2017, San Diego, CA.

C.E. Slone, D.H. Bechetti, J.N. DuPont, M.J. Mills, "Localized deformation under severe microstructural gradients", National Science Foundation Center for Integrative Materials Joining Science for Energy Applications Meeting, January 2017, Columbus, OH.

C.E. Slone, M.J. Mills, "Measurement of strain localization during creep of a polycrystalline superalloy using SEM-based digital image correlation", MS&T16, October 2016, Salt Lake City, UT.

C.E Slone, D.H. Bechetti, J.N. DuPont, M.J. Mills, "Local measurement of creep deformation in polycrystalline superalloys", TMS 2016, February 2016, Nashville, TN.

C.E. Slone, D.H. Bechetti, J.N. DuPont, M.J. Mills, "Fundamental understanding of localized deformation under severe microstructural gradients", National Science Foundation Center for Integrative Materials Joining Science for Energy Applications Meeting, July 2014, Golden, CO.

## Project Experience

Dr. Slone has applied his expertise to help clients understand and solve problems in many different industries. Selected examples are described below:

**Energy and Utilities**

- Gasification technology: investigated several aspects of gasification facilities including chloride corrosion pitting in stainless steel process piping and stress corrosion cracking of dissimilar metal injection lance welds.

- Linear actuator springs: analyzed unexpected deformation and failures in nickel-base superalloy springs designed for high temperature applications.
- High-voltage fuses: performed a failure analysis on high-voltage fuses that were igniting under normal electrical loads.
- Solar power components: investigated aspects of components for solar power generation arrays, including cracking in steel torque tube couplers and galvanized coatings for steel components designed to endure 40 years of environmental exposure.

**Oil and Gas**

- Ongoing transmission integrity management: conducted over a dozen direct cause assessments associated with cutout-for-cause piping components for a large utility operator. Dr. Slone has investigated causes including stress corrosion cracking, selective seam weld corrosion, third party mechanical damage, welding deficiencies, and manufacturing issues, among others.
- In-service leaks and welding burn-throughs: conducted several failure analyses on leaking gas transmission pipelines and welding burn-throughs.
- Crude oil release litigation: supported litigation efforts related to an oil release from a leaking pipeline, which included analyzing in-line inspection (ILI) data.
- Petrochemical facility process piping: supported a multidisciplinary investigation of corrosion in piping at a petrochemical facility, including general corrosion in carbon steel pipes and pitting corrosion in stainless steel pipes. The corrosion was facilitated by delays in the pre-commissioning process for the pipe works, which left standing water in the pipes.
- Subsea pipeline arbitration: assessed documentation relating to a leaking subsea fuel oil pipeline in support of an international arbitration matter.
- Crude oil release: performed a failure analysis following crude oil release from a steel pipe. The direct cause of failure was determined to be internal corrosion.
- Gas pipeline explosion litigation: supported litigation efforts related to a gas pipeline explosion, which was caused by hydrogen embrittlement of hard spots that were produced during pipe manufacturing. Dr. Slone's support included analysis of in-line inspection (ILI) data per API 1163.
- Pressure vessel support weld cracking: investigated the cause of cracking that ran through a stiffener support and the adjacent weld to the body of a pressure vessel. Recommendations were made to the client about evidence preservation because the fractured components were extensively damaged during extraction, resulting in an inconclusive analysis.

**Industrial Machinery, Equipment, and Facilities**

- Gas turbine investigation: investigated the catastrophic failure of a compressor blade in a gas turbine. The analysis included assessment of non-destructive evaluation techniques and identification of cracking in additional blades. The failure and additional cracks were found to be caused by metal fatigue.
- Evaporator fan analysis: analyzed cracking in the duplex stainless steel impeller of a zero liquid discharge evaporator fan. Cracking was caused by high concentrations of chlorides that led to stress corrosion cracking.
- Mud drum and steam drum analyses: investigated leaks and cracking in boiler mud drum and steam drum walls caused by stress corrosion cracking.

**Buildings and Structures**

- Fractured girder investigation: supported failure analysis efforts related to fractures of steel girders. The cracks that led to the fractures were initiated by thermal cutting of the girders.

- Fractured steel bolts: performed a direct-cause failure analysis of bolts used to secure a structural steel moment-resisting frame system. A number of bolts were found to have fractured due to quench cracking and hydrogen-assisted cracking/hydrogen embrittlement.

**Consumer Products and Sporting Goods**

- Fractured bicycle components: performed direct cause failure analyses on fractured bicycle spindles, spokes, and frames for multiple companies. Causes of failure have included hydrogen-assisted cracking/hydrogen embrittlement, sub-surface manufacturing flaws, and grain boundary embrittlement due to incipient melting of an aluminum frame.
- Wearable device warping: investigated austenitic stainless steel housings for wearable electronic devices that were warping during the manufacturing process.
- Frying pan rivet caps: analyzed frying pans on which rivet caps were being ejected at high speeds during use.

**Vehicles and Personal Transportation**

- Battery fires: engaged in two multi-disciplinary investigations into vehicle battery fires. Dr. Slone's role was assessing arcing damage and corrosion on metal components around the apparent fire initiation site.
- Drive clutch failures: investigated failures of cast aluminum drive clutches from a brand of off-road vehicles. The failures were related to porosity in the cast components.
- Scooter stem fractures: analyzed fatigue failures of handlebar stems on electric scooters.

**Medical Devices**

- Orthopedic implant: supported litigation efforts related to the fractured screws on a cervical spine fixation implant.
- Surgical devices: performed several failure analyses related to surgical grippers, clips, and other hardware. Dr. Slone has also engaged in proactive work that involved comparing components of the same design that were manufactured by different processes.

 