Corrosion to Fracture: Lessons from Naval Research and Forensic Investigations

Abstract: Engineered materials do not fail in isolation. Their service performance reflects materials selection in design and interactions among alloy composition, phase distribution, microstructure, processing, mechanical loading, and environmental exposure. Drawing on naval research and forensic investigations, this presentation examines environmentally-assisted failures, misuse, and approaches to mitigation. Case studies include 1) stress corrosion cracking in sensitized aluminum-magnesium shipboard alloys and ultrasonic surface treatments; 2) hydrogen-assisted cracking in duplex stainless steels, where disparate ferritic and austenitic phases contribute to orientation-dependent deformation and crack propagation; 3) and galvanic corrosion of zinc-coated steel wire ropes in outdoor environments. The analysis emphasizes fractography to identify operative deformation and fracture mechanisms, supported by metallography, corrosion morphology, fracture mechanics, and mechanical testing. These methods distinguish material susceptibility and design deficiencies from environmental degradation, improper use, and inadequate maintenance. Prevention strategies include materials selection, management of galvanic coupling and residual stress, protective coatings, inspection, and timely replacement.

Biography: Marc Zupan, Ph.D., is a materials and solid mechanics engineer. He is Principal and Materials Practice Director at APEX Applied Science and Engineering and Associate Professor Emeritus of Mechanical Engineering at UMBC- University of Maryland, Baltimore County. Dr. Zupan earned his Ph.D. and M.S. specializing in Materials and Solid Mechanics in the Department of Mechanical Engineering at the Johns Hopkins University, and his B.E. in Mechanical and Aerospace Engineering from the University of Dayton. He subsequently conducted postdoctoral research at the University of Cambridge's Micromechanics Centre as a National Science Foundation International Research Fellow. He also served as an Academic Associate at Pembroke College, Cambridge. Dr. Zupan has directed research programs for the Office of Naval Research and collaborated with the Naval Surface Warfare Center, Carderock Division, where he held a Research Faculty appointment. His research collaborations also included the Naval Research Laboratory in Washington, D.C., and the Naval Air Systems Command (NAVAIR) at Naval Air Station Patuxent River. He also served as a Research Fellow at the U.S. Army Research Laboratory. As a Fulbright Scholar at the University of Porto in Portugal, Dr. Zupan studied global engineering and materials supply chains, including materials recycling, qualification, and certification. He serves as a Fulbright Alumni Ambassador, continuing his engagement in international academic exchange. He has also helped advance international engineering education through partnerships between UMBC and Hochschule Osnabrück and the UAS7 network of German Universities of Applied Sciences.