UNIVERSITY of HAWAIʻI at MĀNOA
MECHANICAL ENGINEERING

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10:30am-11:30am
Bilger Hall 152

Failure as a Design Feature: A Computational Framework for Fracture-Driven Optimization

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Abstract

Traditional structural design focuses on preventing fracture, limiting applicability in systems that require controlled, predictable failure. This dissertation developed a dual-physics optimization framework that couples finite element analysis (FEA) with peridynamic fracture simulation to design structures where engineered failure is a primary objective.

The framework linked DOLFINx-based transient FEA for impact stress evaluation with Peridigm peridynamic fracture modeling through a fracture-aware thickness cap that prevents stress-driven thickening from compromising fracture performance. The parameterized thin shell structure, with independent thickness and fracture zone definitions per sectoral region, enabled automated mesh generation, multi-orientation drop simulation, and crack-line connectivity evaluation within a closed optimization loop. Six optimization methods were compared across band-count and initial-thickness sensitivity studies.

The breakaway weight shell for Hawaiian pelagic longline fisheries served as the validation application. Flyback events, in which a failed fishing line accelerates the weighted swivel at high speed, pose serious injury risks to crew; the breakaway shell must survive normal handling while fracturing reliably upon flyback impact. Experimental testing established the loading environment, and peridynamic simulations verified that fracture propagated along designed failure planes.

The optimization achieved stress feasibility while maintaining fracture performance, with methods converging to qualitatively viable thickness profiles. The peridynamic fracture simulations confirmed that geometric selectivity alone directed crack propagation along designed failure planes without requiring differentiated material properties. The fully automated framework, from parameterized geometry through fracture evaluation, demonstrated that treating fracture as a design variable within a dual-physics loop is a viable and generalizable approach for frangible structural systems.

About the Speaker

Speaker Name PhD Candidate Matthew Nakamura completed his BS degree in spring 2020 and his MS degree in spring 2021, as one of the first participants in the new combined pathway Bachelors-and-Masters program in the University of Hawaii Mechanical Engineering Department. Joining Dr. Joseph Browns Nanosystems lab in October of 2018 and works on Wireless Sensor Packages/Networks as a platform to test sensors and environmental monitoring. His work has since expanded into the design of instrumentation and material testing systems, and into mechanical design utilizing open-source simulation software and structural optimization techniques, including coupled finite element and peridynamic fracture analysis for topology optimization of protective structures.

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