2021 Engineering Mechanics Symposium Program

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Session A **Chair: Dave Dillard**	**Session B** **Chair: Jonathan Boreyko**
9:30-9:45 **Reflections on Steering Cracks (and Herding Cats)** **Dillard, David**, *Biomedical Engineering & Mechanics*	9:30-9:45 **Mechanics of Water Harvesting with a Fog Harp** **Boreyko, Jonathan**, *Mechanical Engineering* Kowalski, Nicholas, *Mechanical Engineering* Shi, Weiwei, *Engineering Mechanics* Kennedy, Brook, *School of Architecture and Design*
Fracture has been at the heart of terrifying catastrophic failure events, of the gradual deterioration and breakage of everyday products we use, and even of the intriguing beauty growing cracks can leave in their wake, such as fractures of geological features or intentional crazing in a ceramic artist's handiwork. In all of these scientific, technological, and aesthetic applications, the growth of cracks proceeds as guided by the underlying physics, some aspects of which remain better understood than others. And while much interest has been devoted to understanding, imaging, and characterizing fracture patterns in order to understand why they occurred and how to prevent in the future, there is also interest to intentionally steer cracks in ways to provide new insights and new artforms. Valid reasons exist for attempting to induce interfacial failure modes in bonded systems to effectively interrogate the bond and quantify interfacial adhesion.	It has recently been demonstrated that harps harvest substantively more fog water than conventional mesh nets, but the optimal design for fog harps remains unknown. Here, we systematically vary key parameters of a scale-model fog harp: the wire material, wire pitch, and wire length to find the optimal combination. We found stainless steel to not only be the best non-hydrophobic wire material, but nearly as effective as Teflon-coated wires. The best choice for the wire pitch was coupled to the wire length, as the smallest pitch collected the most water for short harps but was hampered by tangling for taller harps. Accordingly, we use an elastocapillary wire tangling model to successfully predict the onset of tangling beyond a critical length for any given wire pitch. Combining what we learned, we achieved a water harvesting efficiency of 17% with an optimized stainless steel harp, over three times higher than that of the current standard of a Raschel mesh. These results suggest that an optimal fog harp should feature high-tension, uncoated wires within a large aspect ratio frame to avoid tangling and promote efficient and reliable fog harvesting.
9:45-10:00 **Durability Analysis of Helical Coil Spring in Vehicle Suspension Systems** **Kumar, Dhananjay**, *Engineering Mechanics* Thangjitham, Surot, *Biomedical Engineering and Mechanics*	9:45-10:00 **Understanding the occurrence of 2P wakes in the wake of an oscillating cylinder at low Reynolds number** **Masroor, Emad**, *Engineering Mechanics* Stremler, Mark, *Biomedical Engineering and Mechanics*
The suspension system in vehicles supports the vehicle's road stability and ride quality by scaling down the vibration responses resulting from road surface's roughness. This research focuses on the fatigue life analysis of coil spring component. Structural analysis is conducted on the 3D model of helical coil spring to investigate deformation and stress responses. Modal analysis evaluates the characteristics of vibration i.e., natural frequencies and mode shapes. Frequency Response data (from cyclic and shock loading) is generated after performing the harmonic analysis on the spring. Dynamics and performance of spring are analyzed under complex shock loading conditions. Fatigue life estimation of vehicle suspension spring is performed using the stress data evaluated from frequency response analysis. Rain-flow cycle counting approach is used for obtaining equivalent count of loading cycles. Using stress-life (S-N) approach, fatigue life of spring is predicted from the stress response data. The durability analysis can be utilized in the automotive industry to improve reliability of vehicles. The outcome of this research can contribute to analysis and design of modern smart vehicles.	The laminar flow over a circular cylinder oscillating transversely to the oncoming flow is a useful setting in which to study vortex-induced vibrations (VIV). VIV are ubiquitous in natural and engineered systems: they are responsible for wind loads on skyscrapers, dictate the design parameters of undersea cables, and can be harnessed for energy harvesting from small-scale riverine and tidal flows. In this talk, we will examine the appearance (or lack thereof) of the 2P mode of vortex-shedding behind an oscillating cylinder at low Reynolds number, in which two pairs of vortices are shed during each cycle of the cylinder's motion. The presence of this highly organized mode of vortex-shedding is associated in the literature with an "upper branch" of vortex-induced vibrations, and it is typically understood that this mode only occurs at high Reynolds numbers. Recent experiments by our research group, however, have shown the 2P mode occurring in low-Reynolds number experiments as well (Yang, Masroor and Stremler arXiv:2101.00108). We will discuss the implications of these results for VIV and present the results of ongoing experiments to explore this phenomenon further.

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Session A **Chair: Dave Dillard**	**Session B** **Chair: Jonathan Boreyko**
10:00-10:15 **An Efficient Methodology for Predicting the Dynamic Response of Multilayered Continua** **Burns, Devin**, *Engineering Mechanics* Batra, Romesh, *Biomedical Engineering and Mechanics*	10:00-10:15 **Wall shear stress distributions in an annular lid-driven cavity flow** **Sadagopan, Sudharsan**, *Engineering Mechanics* Hyler, Alex, *CytoRecovery, Inc.* Stremler, Mark, *Biomedical Engineering and Mechanics*
As fiber-reinforced composites have become more ubiquitous in structural applications, the need to understand and accurately predict their transient behavior in complex loading environments has increased. The challenges include satisfying displacement and traction continuity conditions at layer interfaces, identifying when, where, and why the structure fails first, and satisfying boundary conditions. We analyze plane stress deformations of sandwich beams caused due to shock loads by using a least-squares space-time finite element method, Hooke's law for transversely isotropic materials and a mixed layer-wise formulation of governing equations in which transverse stresses, velocities, and in-plane normal strain at a point are taken as unknowns. The sum of residuals in the governing equations, the initial conditions and the boundary conditions on all surfaces is minimized. A Tsai-Wu failure criterion is adopted to determine where and when a material point in the beam fails. The software has been verified by using the method of manufactured solutions. Convergence of the numerical solution with respect to the time-step size and the spatial discretization has been studied.	In many applications it is desirable to produce a consistent, predictable, and (preferably) uniform flow-induced wall shear stress. A fluid-filled circular lid-driven cavity, with one fixed and one rotating disk, is a classic system for generating steady shear flow in a bounded domain. We extend consideration to an annular ring with a rotating lid, a system that is motivated by an investigation of fluid shear stress effects on cells. In the current study, the shear stress distribution on the fixed wall has been investigated computationally in both systems for Re<1000, where the Reynolds number (Re) is based on the gap thickness and lid velocity. For low Re and small radial locations, the flow is axisymmetric and the rotating disk results agree with the analytical solution for an unbounded domain. However, for higher Re values, spatially periodic, spiral-shaped pressure and shear stress variations were observed. The validity of representing the averaged time-varying shear stress values with a steady state model will be discussed. The outcome of this study helps further the development of robust models for examining flow-induced shear stress effects on cells.
10:15-10:30 **Characterizing fracture toughness of carbon nanotube and graphene nanoplatelet doped epoxy nanocomposites** **Shirodkar, Nishant**, *Aerospace and Ocean Engineering* Seidel, Gary, *Aerospace and Ocean Engineering*	10:15-10:30 **Effect of Bending Stiffness on Foil Bearings** **Habibi, M.**, *Engineering Mechanics* Cramer, M.S., *Summit Science* Thangjitham, S., *Biomedical Engineering and Mechanics*
The experimental study presented herein, demonstrates the possibility of enhancing the fracture toughness properties of structural epoxy composites by doping the matrix material with nanoparticles such as graphene nanoplatelets (GNPs) and carbon nanotubes (CNTs). In this study, EPON 862+W Curing Agent is enhanced by adding 0.8% nanoparticles by weight. To understand the effects of adding different nanoparticles on the fracture toughness properties, compact tension specimens of four material systems, namely: neat epoxy, CNT-epoxy, GNP-epoxy, and CNT/GNP-epoxy are fabricated in accordance with ASTM D5045. Fracture toughness tests were conducted via a displacement controlled test setup. Significant enhancements in peak load carrying capacity, fracture displacement, fracture energy and critical stress intensity factor, K_IC, were observed. K_IC values for GNP-epoxy was observed to be 80% higher than the neat epoxy suggesting a considerable increase in the epoxy's ability to resist fracture and crack growth. An increase of 100% in peak load carrying capacity of GNP-epoxy compared to neat epoxy was observed.	Foil bearings embed a thin metal strip or plate between the known moving and stationary surfaces. The strip or plate is supported by a series of springs. The flexibility of the foil and springs will modify the film thickness which, in turn, modifies the hydrodynamic load on the foil. Thus, the mechanics problem is a nonlinear fluid-structure interaction. In the present study we consider a highly simplified model where the flow is modeled as laminar, incompressible, two-dimensional, and governed by the appropriate Reynolds equation. The foil is modeled as an Euler-Bernoulli beam and the springs are modeled as a linearly elastic foundation. Numerical and approximate solutions are used to demonstrate that bending resistance is negligible over most of the foil for parameters typical of gas bearings. We also demonstrate that thin boundary layers form near the supports. The advantage of this work and future studies based on it include the possibility of significant simplifications in computational studies and guidance for the construction of grids in brute force computational work. The very large shears identified here can have important consequences for reliability and design.

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10:30-11:00 Poster Session Chair: Mark Stremler

Physics-based Constitutive Equation for Thermo-Chemical Aging in Elastomers based on Crosslink Density Evolution

Najmeddine, Aimane, *Civil and Environmental Engineering*
Shakiba, Maryam, *Civil and Environmental Engineering*

This work presents a novel physics-based constitutive equation to predict the thermo-chemical aging in elastomers. High-temperature oxidation in elastomers is a complex phenomenon. The elastomer's microstructure undergoes chain scission and cross-linking of macromolecular network under high temperature and oxygen diffusion conditions. In this work, we modify the Arruda-Boyce well-known eight-chain constitutive equation to incorporate the additional Helmholtz free energy due to network changes within the elastomer's microstructure. The effect of network crosslink reforming in modifying the shear modulus and chain segments is considered. The modification is based on chemical characterization tests, namely the equilibrium swelling experiment to measure the crosslink density evolution. The proposed constitutive equation is validated with respect to a comprehensive set of experimental data available in the literature that were designed to capture thermo-chemical aging effects in elastomers. The comparison showed that the constitutive equation can accurately predict the mechanical tests based on crosslink density evolution input.

Scaling the Thermal-Structural Response in Fire Resistance Tests

Gangi, Michael, *Engineering Mechanics*
Case, Scott, *Civil and Environmental Engineering*
Lattimer, Brian, *Mechanical Engineering*

ASTM E119 is a large-scale test method used to qualify building assemblies for fire resistance. For floor and wall assemblies, typical test specimens are required to be at least 3.0 m (10 ft.) or more on each side to represent the failure phenomena in a building environment. Because the ASTM E119 test standard requires specialized furnaces and large-scale assemblies, it is very expensive to perform. In the early stages of product development, our project aims to replace costly ASTM E119 tests with inexpensive bench-scale tests during the material screening phase to accelerate research and development. As a result, the focus of this research is to develop scaling laws for reducing the size of the test specimen while maintaining the same thermal and structural response exhibited in a large-scale ASTM E119 test. This presentation develops a scaling methodology for the structural and thermal response of the ASTM E119 test. Structural response is maintained with geometric scaling. Thermal response is maintained with a combination of Fourier number scaling and by matching the boundary conditions on both the exposed and unexposed surfaces.

Penetration Resistance of Cast Metal-Ceramic Composite Lattice Structures

Umanzor, Manuel, *Materials Science and Engineering*
Batra, Romesh, *Biomedical Engineering and Mechanics*
Williams, Christopher, *Mechanical Engineering*
Druschitz, Alan, *Material Science and Engineering*

A challenging issue in armor mechanics is to simultaneously reduce weight and increase impact resistance of a target. In this work we explore experimentally and computationally the impact resistance of a cast metal-ceramic lattice structure having ceramic tiles encapsulated in the metal matrix. A hybrid additive manufacturing/metal-casting technique was used to fabricate lightweight aluminum alloy A356, treated to the T6 condition, impact-resistant lattice structures with embedded silicon carbide tiles of varying thicknesses. The resistance to penetration was evaluated upon high velocity impacts from 0.30-cal AP M2 armor-piercing projectiles and 7.62 mm x 51 mm M80 full metal jacket ball rounds. Tests at different striking velocities at normal incidence revealed that embedding a hard ceramic improved the penetration resistance of an otherwise soft metal matrix. Real-time X-ray imaging and scanning electron microscopy techniques were used to ascertain the quality of the castings, as well as the damage caused to the target.

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Session A Chair: John Domann	**Session B Chair: Nicole Abaid**
11:00-11:15 **Generalizing Chu's Limit: Fundamental frequency, size, bandwidth restrictions for acoustic systems** **Domann, John**, *Biomedical Engineering and Mechanics*	11:00-11:15 **Eavesdropping like a bat: fusing active and passive sonar for simultaneous localization and mapping** **Abaid, Nicole**, *Mathematics* Jahromi Shirazi, Masoud, *Engineering Mechanics*
Chu's limit is provides one of the foundational restrictions in modern antenna theory. The limit reveals that for a lossless linear time invariant (LTI) antenna system, there is a fundamental relationship between the size, frequency, and bandwidth of the device. Specifically, if an antenna fits inside a sphere of a given radius, Chu's limit provides the minimum quality factor for the system. Decreasing the size of an antenna increases the minimum quality factor, which reduces the available bandwidth and therefore operational utility of the device. This talk will demonstrate that Chu's limit can be generalized to other LTI systems, with a focus on acoustics. Amongst other things, the generalized limit provides a key restriction for energy harvesting devices, wireless power transfer, and explains why it is so challenging to make small headphones (earbuds) with the same sound quality as large speakers.	Among so-called active sensors that use self-generated signals, sonar sensors are challenging to implement compared to lidar and radar due in part to their limited angular field of sensing. A common solution to this challenge is scanning sensors which sweep an angular range with successive measurements. However, scanning sensors are problematic due to the relatively slow speed of the sound as well as the sonar head inertia. Studies of bat behavior suggest that bats may eavesdrop on their conspecifics during group flight. In other words, they fuse information gathered by their own active sonar with information they receive through passively listening to peers. Since bats are extremely skilled in using sonar, this behavior inspired us to investigate whether fusing active and passive sonar can be a novel strategy for implementing sonar sensors. We define a new model of fused sensing and use numerical simulation to answer this question on the test bed problem of simultaneous localization and mapping (SLAM). The simulation results show that, when the angular range of active sonar and the associated noise are relatively small, the robot's performance in solving SLAM is improved.
11:15-11:30 **A One-Dimensional Constitutive Model for Magnetostrictive Materials** **Imhof, Alecsander**, *Engineering Mechanics* Domann, John, *Biomedical Engineering and Mechanics* Goforth, Michael, *Engineering Mechanics*	11:15-11:30 **Quasi-2D hearing for a 3D world: a better model for hearing in a parasitoid fly** **Mikel-Stites, Max**, *Engineering Mechanics* Saleco, Mary, *Biomedical Engineering and Mechanics* Socha, Jake, *Biomedical Engineering and Mechanics* Staples, Anne, *Biomedical Engineering and Mechanics*
Macroscale models of magnetoelastic materials have difficulty simulating the inherently non-linear magneto-strictive response, and often resort to oversimplifications. In contrast, micromagnetic simulations are the gold-standard continuum model of magnetostriction but their use is limited to small systems. To bridge micromagnetics to the macroscale some prior work has utilized statistical physics. The main challenge of this approach is that the requisite integral expressions do not generally possess closed form solutions and therefore require numerical approximations. The focus of this research is on simplifying a general three-dimensional model, to one dimension leading to closed form solutions for magnetization and magnetostriction. The numerical accuracy of the exact solutions will be compared to an accurate, but computationally expensive numerical integral with relative error set at machine precision. This will demonstrate the exact solutions can routinely become numerically ill-conditioned, and present corrective actions. To conclude, the model will be used to simulate the magnetization of different compositions of Galfenol subject to magnetic fields and mechanical stresses.	*Ormia ochracea* is a parasitoid fly known for its precise sound localization abilities, which it uses to locate its preferred host, Gryllidae crickets. The existing model for *O. ochracea* hearing accurately predicts the interaural amplitude difference (ITD) between the tympana for all incident sound angles. However, it fails to predict the interaural time delay (IAD) accurately for high incident sound angles. To explore this failure, we used synchrotron radiation microtomography to determine the 3D morphology of the tympana of two *O. ochracea* specimens. Previous models treat these structures as 2D-like plates, but imaging reveals that the tympana are complex and three-dimensional in nature. Using this new information, we add a term representing the tympanum's elastic response in the lateral direction and recover the observed IAD for all incident sound angles. This work demonstrates that hearing in *Ormia ochracea* involves acoustic information and physiological responses in two primary planes rather than one. This improved model may lead to the improved design of microscale auditory devices, including insect-inspired directional microphones and hearing aids.

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Session A Chair: John Domann	**Session B Chair: Nicole Abaid**
11:30-11:45 **Jumping Ice**	11:30-11:45 **Modeling Lost Person Dynamics for Wilderness Search and Rescue**
Mukherjee, Ranit, *Engineering Mechanics* Ahmadi, S. Farzad, *UC Santa Barbara* Zhang, Hongwei, *Mechanical Engineering* Qiao, Rui, *Mechanical Engineering* Boreyko, Jonathan, *Mechanical Engineering*	**Hashimoto, Amanda**, *Engineering Mechanics* Heintzman, Larkin, *Electrical and Computer Engineering* Koester, Robert, *dbS Productions LLC* Abaid, Nicole, *Mathematics*
Here, we show a surprising phenomenon where a frost dendrite breaks off from the mother frost (or surface) and jumps toward an opposing film or droplet of water with a velocity of about 1 m/s. Jumping was not observed when the opposing water was replaced with a non-polar liquid or the frosted substrate was placed in an isothermal condition room. These experimental controls suggest an electrostatic mechanism for the jumping effect. Mismatches in the mobilities of the charge carriers in ice along the temperature gradient make the top of the growing frost negatively charged, which in turn induces an opposite charge on the opposing liquid and sets up an electric field between the frosted surface and the liquid. The electric field theory is supported by the experiments where we observed vastly different kinematics of the jumped dendrites in the presence of water film and water droplet. Further understanding of this surprising jumping frost events can not only answer some longstanding questions regarding the charge separation process in ice, but also enable a novel de-icing technique for practical applications.	Thousands of people are reported lost or missing in the United States every year and locating these missing individuals alive and as rapidly as possible depends critically on coordinated search and rescue (SAR) operations. As time passes, the search area grows, survival rate decreases, and searchers are faced with an increasingly daunting task of searching a large area in a short amount of time. To optimize the search process, mathematical models of lost person behavior with respect to landscape can be used in conjunction with current SAR practices. In this talk, we introduce an agent-based model of lost person behavior that can be used to improve current methods for wilderness SAR. The model defines agents moving on a landscape with behavior considered as a random variable. The behavior uses a distribution of six known lost person reorientation strategies to simulate the agent's trajectories. We systematically simulate a range of possible behavior distributions in the model and compute a behavioral profile for a hiker by fitting with a database of lost person cases. We validate these results with a leave-one-out analysis.
11:45-12:00 **Using Frost to Promote Cassie Ice on Hydrophilic Pillars**	11:45-12:00 **A Lagrangian Stochastic Model for Particle Transport**
Park, Hyunggon, *Engineering Mechanics* Ahmadi, S. Farzad, *UC Santa Barbara* Boreyko, Jonathan B, *Mechanical Engineering*	**Nimmala, Bhargavi**, *Engineering Mechanics* Ross, Shane, *Aerospace and Ocean Engineering* Foroutan, Hosein, *Civil and Environmental Engineering*
We develop a novel approach to suspend ice in the air-trapping Cassie state without requiring any fragile hydrophobic coatings or nanostructures. First, frost was preferentially grown on the tops of hydrophilic aluminum pillars due to their sharp corners and elevation over the non-condensable gas barrier. Subsequently, Cassie ice was formed by virtue of the impacting droplets getting arrested by the upper frost tips. A scaling model reveals that the dynamic pressure of an impacting droplet causes the water to wick inside the porous frost faster than the time scale to impale between the pillars.	Pollen from a field, aerosols from the sea, droplets from a cough – understanding how particles travel downwind from a source is a common and vital challenge. The Lagrangian Stochastic (LS) model computes downwind concentrations by following the random fluctuating paths of individual particles and computing a time average at a specific location. It is computationally lighter than CFD-type models, more effective on smaller scales than Eulerian-advection models, and more fine-tuned than the Gaussian plume model. We have validated a previously established LS model by replicating field measurements and downwind concentration profiles from a published work. We are now verifying its efficacy on aerosol concentration data collected on the Florida coast from a Red Tide harmful algae bloom. Using this data, we can estimate flux of aerosols out of the sea and project how far inland they may go. This LS model will then be used in our own field study in collaboration with the University of Tennessee Knoxville to better understand the transport of hemp pollen from a field and limits of cross-pollination. The LS model allows us to answer the question, "How far does it go?"
12:00 – 13:00 Lunch Break	

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Session A **Chair: Gary Seidel**	**Session B** **Chair: Anne Staples**
13:00-13:15 **Modeling of Strain, Damage, and Hot Spot Detection in Nanocomposite Bonded Energetic Materials via Thermo-Electro-Mechanical Peridynamics**	13:00-13:15 **Coral colony hydrodynamics**
Seidel, Gary, *Aerospace and Ocean Engineering* Povolny, Stefan, *Aerospace and Ocean Engineering* Talamadupula, Krishna, *Mechanical Engineering*	**Staples, Anne**, *Biomedical Engineering and Mechanics* Hossain, Monir, *Engineering Mechanics*
Plastic-bonded explosives consist of energetic grains having high energy densities embedded in polymer binders. Under the influence of mechanical insults, formation of hot spots may occur within such materials which may lead to ignition. Multiple studies have concluded that frictional heat at fracture surfaces is an important hot spot formation mechanism. Thus, this study seeks to computationally model the frictional mechanisms for hot spot formation at the grain-resolved microscale. Introduction of carbon nanotubes into the polymer binder results in a functionalized nanocomposite binder with significant piezoresistivity that could be used to monitor hot spots. The piezoresistive nature of the binder has thus been introduced in the computational model through effective piezoresistive coefficients. Simulations performed on a grain-scale representative volume element correspond to low-velocity impact loading, thermal hot spot loading and a combination of these loads, during which changes in the resistance as a result of strain and damage are monitored.	Coral reefs rely on the local flow field to carry out physiological processes like respiration and nutrient uptake. Despite the importance of corals and the pervasive threats facing them, characterizing the local hydrodynamics between their branches has remained a significant challenge. Here, we investigate the effects of colony branch density and surface roughness on the flow field using three-dimensional immersed boundary, large-eddy simulations for four different colony geometries under unidirectional oncoming flow conditions. We compare loosely and densely branched *Pocillapora* colonies, and *Monitipora* colonies with and without roughness elements called *verrucae*. We found that the mean velocity profiles changed substantially in the center of the dense colony, becoming reduced at middle heights where flow penetration was poor, while the profiles in the loosely branched colony remained similar throughout the colony. In the *Montipora* colonies, counterintuitively, the colony without verrucae produced almost double the maximum Reynolds stress magnitude above the colony compared to the colony with verrucae, implying that the smoother colony will have enhanced vertical mass transport.
13:15-13:30 **Reduced-order Structure-Property Linkage for Multifunctional CNT-Polymer Nanocomposites via Machine Learning**	13:15-13:30 **Climbing strategies of cicadas across vertical 'gaps' of low friction**
Shah, Kavan, *Mechanical Engineering* Seidel, Gary, *Aerospace and Ocean Engineering*	**Pulliam, Joshua**, *Engineering Mechanics* Weiss, Talia, *Engineering Mechanics* Salcedo, Mary, *Biomedical Engineering and Mechanics* Hernandez, Alyssa, *Harvard University* Socha, Jake, *Biomedical Engineering and Mechanics*
The effective properties of CNT-polymer nanocomposites depend on the constituent phase properties and on microstructural information. In this work, the microstructure of computationally generated CNT-polymer nanocomposite realizations was statistically characterized via spatial two-point correlation functions. Several types of two-point correlation functions were considered namely pair correlation functions, ensemble and volume-averaged two-point correlation functions, lineal path functions and two-point cluster functions. Each of these capture specific features of the microstructure, such as the volume fraction, preferred orientation, shape, size, clustering, and dispersion of the phases, which drive the effective properties of interest including elastic stiffness, conductivity, and piezoresistivity. Principal component regression (PCR) using volume averaged two-point correlation functions resulted in 95% prediction accuracy for the stiffness coefficients. Lineal path functions and two-point cluster functions were constructed to predict the conductivity and piezoresistivity coefficients.	Limb adaptations allow insects to navigate terrain while maintaining stability, enabling behaviors such as climbing, digging, and skimming across water. Structures such as claws allow insects to attach to uneven surfaces. Periodical cicadas (genus: *Magicicada*) have shown a preference for small-diameter branches because they use them to lay eggs. Often, these locations are at the ends of tree branches, where stability is key. However, how cicadas navigate, grip, and support themselves on thin tree surfaces is largely unknown. Here, we investigated how two species of cicada climb and interact with areas of low friction. We recorded 701 trials of cicadas climbing on PVC and plastic pipes of four diameters (5.0, 15.9, 21.6, 33.5 mm) using a synchronized camera array (Hero 4 Black, GoPro). The pipes were wrapped in matting to provide a high-friction surface for climbing. This matting was separated to provide areas of low friction. For the four largest pipes, success rate of crossing decreased with increasing gap size, from 85.4% (6 mm) to 10.5% (30 mm), and cicadas could not cross the largest gap (36 mm). However, the smallest diameter pipe had a 100% success rate across all gap sizes.

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Session A Chair: Gary Seidel	**Session B** Chair: Anne Staples
13:30-13:45 **Multiscale Modeling of Damage Response in Composites Reinforced with CNT Fibers**	13:30-13:45 **Fiber force microscopy: reconstructing forces of cell migration on nanofiber networks**
Genckal, Neslihan, *Aerospace and Ocean Engineering* Povolny, Stefan, *Aerospace and Ocean Engineering* Seidel, Gary, *Aerospace and Ocean Engineering* Cheng, Shengfeng, *Physics*	**Kale, Sohan**, *Mechanical Engineering* Padhi, Abinash, *Mechanical Engineering* Daw, Arka, *Computer Science* Talukder, Maahi, *Mechanical Engineering* Karpatne, Anuj, *Computer Science* Nain, Amrinder, *Mechanical Engineering*
This study shows the effect of CNT fibers on the material strength of epoxy-based composites. In order to simulate the material behavior properly, a hierarchical multiscale framework is employed. Due to the lack of spatial derivatives in its governing equations and therefore advantages in case of singularities, PD theory is used to solve the problem. First, the limitation of the horizon in the PD theory is overcome by a strategy used to have a free horizon. The method used is calibrating the critical stretch by using the macro level failure strain. A dogbone specimen is used for this purpose. The calibration is considered successful when the bond level failure stretch is within an acceptable error compared to the macro level strain. The calibration is done for only-epoxy and only-fiber materials, which are then used in the hexagonal and random RVEs. Different hexagonal RVEs of neat epoxy, 1, 5, 10 and 25% and random RVEs of neat epoxy, 0.5%, 1%, and 2% of VF of fibers are used. The effective material properties of the RVEs are obtained after tension tests done on the RVEs, which are then used in the macroscale compact tension specimen.	Cells thrive in fibrous environments composed of fiber networks of wide range of fiber sizes and spacings in both physiological and pathological settings. Nanofiber networks of controlled architecture, generated using STEP technique, is an effective platform to investigate cell shape plasticity and cell migration relevant in cancer metastasis and wound healing. Yet the mechano-biological characterization is incomplete without knowledge of the contractile forces exerted by cells that deform and remodel the nanonet. We develop a force microscopy technique to measure the cell exerted forces directly from phase images with the aid of deep learning. The network deformation is extracted from phase images by training a generative adversarial network. The ill-posed inverse problem to get forces from deformations is formulated as a regularized error-minimization problem constrained by the nonlinear mechanics of pre-tensed nanofibers. The inverse method is shown to recover the overall contractility to within 10% for expected signal-to-noise ratios. Taken together, the phase-image based force reconstruction offers a powerful tool to probe cell mechanobiology on nanofiber networks.
13:45-14:00 **Damage and Failure in Blast Loaded Composite Sandwich Structures**	13:45-14:00 **Contractile Strains of the Rat Vagina**
Alanbay, Berkan, *Biomedical Engineering and Mechanics* Batra, Romesh, *Biomedical Engineering and Mechanics*	**Huntington, Alyssa**, *Engineering Mechanics* Abramowitch, Steven, *University of Pittsburgh* Moalli, Pamela, *University of Pittsburgh* De Vita, Raffaella, *Biomedical Engineering and Mechanics*
The high specific strength and the tailorability in desired directions of material properties of fiber-reinforced composites have enhanced their use in aerospace, marine, automotive, and defense industries to protect primary structures such as a damper in a car. A typical composite sandwich structure is composed of outer thin carbon fiber-reinforced epoxy composite face sheets bonded by an adhesive layer to thick either foam or balsa wood or metamaterial core. Inelastic deformations of the core dissipate a large amount of energy and attenuate shock loads impacting the structure. Trustworthy and robust mathematical models are needed for designing lightweight sandwich structures to mitigate a given blast load. With the objective of combining tools for optimization and structural analysis with reduced-order models, we have studied the failure of sandwich structures using the finite element software, Abaqus, in which we have implemented a user-defined material subroutine (VUMAT) for simulating failure initiation and propagation. The computed deflections of laminates for five shock loads available in the literature are found to agree well with the experimental ones.	The ability of the vagina to contract gives rise to a set of active mechanical properties that contribute to the complex function of this organ. The large heterogeneous deformations that the vagina experiences during contractions have never been quantified. Furthermore, there is no consensus regarding differences in contractility along the two primary anatomical directions of the vagina: the longitudinal direction (LD) and the circumferential direction (CD). In this study, vaginal specimens from healthy virgin rats (n=15) were subjected to isometric planar biaxial tests. Contractions were induced at several equi-biaxial stretches by a high concentration potassium solution. The digital image correlation method was used to perform full-field strain measurements during contractions. The vagina was found to undergo significantly higher compressive strains, tensile strains, and contractile forces along the LD than along the CD during contractions. The active mechanical properties of the healthy vagina need to be fully investigated so that detrimental alterations in vaginal contractility, such as those caused by pelvic floor disorders and current treatment strategies, can be prevented.

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Session A **Chair: Gary Seidel**	**Session B** **Chair: Anne Staples**
14:00-14:15 **Exploring the Ideal Bias Conditions for a Magnetoelectric Antennas Considering the Impact of Nonuniform Material Properties** **Goforth, Michael**, *Engineering Mechanics* Imhof, Alec, *Engineering Mechanics* Domann, John, *Biomedical Engineering and Mechanics*	14:00-14:15 **Reduced order modeling of vaginal tissue inflation** **Snyder, William**, *Engineering Mechanics* McGuire, Jeffrey, *Biomedical Engineering and Mechanics* De Vita, Raffaella, *Biomedical Engineering and Mechanics* Iliescu, Traian, *Mathematics*
Magnetoelastic (ME) materials are being explored in the development of new magnetic antennas. These magnetic antennas are being considered due to their theoretical improvement over current technologies when communicating in environments with high losses (e.g. underwater or underground). This work focuses on the design of a resonant three-layer composite composed of a piezoelectric layer, an elastic layer, and a ME layer. A signal is transmitted by modulating the stress state in the ME layer which controls the state of magnetization. Changes in magnetization due to stress leads to changes in the magnetic field surrounding the resonator. This functionality is achieved by driving the layered beam to resonance with the piezoelectric layer. In order to increase the effective range of the antenna one must optimize the structure by choosing a geometry to mitigate the negative effects of the demagnetizing field and by properly biasing the structure. In this talk, an appropriate figure of merit to determine how to optimally bias the structure will be discussed. Additionally, consideration will be given to the impact of these findings on the accuracy of potential reduced order models.	During childbirth the vaginal canal undergoes extreme expansion to accommodate the passage of a baby's head. This expansion causes around 80% of women to experience vaginal tearing during labor. Given how common this injury is, it would be useful to have predictive simulations of tissue deformation so that healthcare professionals could make preemptive treatment decisions for patients. However, finite element (FE) simulations may take hours to run due to the complex geometry and nonlinear material properties of pelvic organs. To be useful in a healthcare setting, results need to be obtained and updated in real-time. To cut down computation time, a reduced order model (ROM) can be used. A ROM uses proper orthogonal decomposition to find a set of modes which characterize the behavior of a full order model using substantially fewer degrees of freedom. As a proof of concept, we trained a ROM to characterize a model of inflation and rupture of murine vaginal tissue based on the experimental setup from J. A. McGuire, C.L. Crandall, S. D. Abramowitch, and R. De Vita, "Inflation and rupture of vaginal tissue," *Interface Focus*, vol. 9, no. 4, 2019.

Keynote Lecture: The Liviu Librescu Memorial Lecture (Meeting ID: 834 2438 2852 Passcode: 799439)
14:30-15:45 **Engineering the Firearm Ecosystem: Research on Media Coverage and Firearm Acquisition in the Aftermath of a Mass Shooting** **Porfiri, Maurizio**, *Tandon School of Engineering, NYU*
The senseless tragedy of April 16 in 2007 marked the beginning of an unprecedented surge of mass shootings in the U.S. history. These events often elicit heated discussion among the public, polarizing opinions on firearm control, as seen and amplified in the media. Previous studies have demonstrated a strong, positive correlation between the frequency of mass shootings and increased firearm prevalence in the U.S. We present an information-theoretic framework, which goes beyond correlational analysis to unravel causal links between mass shootings, media coverage on firearm control, and firearm prevalence. Using empirical data covering from 1999 to 2017, we demonstrate directional information transfer between the time-series of media coverage and the number of background checks, suggesting that media coverage may increase public fear of more stringent firearm control and, in turn, drive firearm prevalence. In other words, people might rush to buy guns because they fear that new regulations may come into effect and their right to acquire a weapon be challenged. Disentangling causation from correlation is critical in firearm research toward empowering policy-makers with strong, objective support for effective policy solutions.