Clemson University Research Experiences for Teachers- 2024 Research Projects

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Research Project Title: Human Factors Evaluation of Novel Tourniquet System for Use By Community Bystanders in Mass Casualty Situations

Faculty Advisor for Research: Prof. John DesJardins (Bioengineering Department)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: Tourniquets are biomedical devices that are used by the military and first responders to quickly occlude blood flow from an extremity wound. Most often, these devices are used by soldiers and medics with specialized training, who can assess the trauma and apply these medical devices quickly and effectively. Tourniquets are often used to stop blood flow after a gun shot or blast wound. Application of tourniquets within the first five minutes of trauma that involves arterial hemorrhage is critical in the saving of the victims life. Unfortunately, there has been a dramatic increase in the number of mass shootings in the USA, that necessitate the wider availability of these tourniquets in community settings such as malls, playgrounds, churches, schools, sporting events and other venues. Similar to the now-prolific availability of AED's (Automated External Defibrillators) that allow a by-stander to apply lifesaving shocks to a person that has had a heart attack, the wider distribution of an automated easy-to-use tourniquet system could have dramatic life-saving potential in places where these mass shootings occur.

In this work, we are partnering with a local medical device manufacturer to conduct a pre-market evaluation of the usability of a new Semi-automated tourniquet system. This human factors focused study will evaluate the potential of lay-people to engage with and effectively use this tourniquet system in a casualty situation. This work will be completed on potentially 100+ community participants over the summer of 2024, in partnership with our industry partners and collaborators in the department of Industrial Engineering.

Research Project Title: Additive Manufacturing of Lattice Structures

Faculty Advisor for Research: Prof. Shunyu Liu (Department of Automotive Engineering)

Project Location: Greenville, SC (International Center for Automotive Research)

Teacher's Research Project: The lattice structure is an essential design for biomedical implants and energy storage devices. For implants, the lattice structure provides a scaffold for new tissue to grow into. Optimizing the spacing and strut thickness of the lattice can tailor the implant to match the stiffness of the surrounding bone. For energy storage devices, the lattice structure provides continuous diffusion pathways for ions and electrons. To satisfy these applications, the lattice structure should be designed to have high specific surface areas and interconnected channels, which requires unique lattice features (e.g., size, shape, distribution, and porosity). Powder-bed additive manufacturing processes, such as laser powder bed fusion (LPBF), are advantageous for flexible design of lattice structures due to their high dimensional accuracy, resolution, and near-net-shaping capability. This research will design and fabricate strut-based and surface-based lattice structures and investigate their mechanical responses via finite element modeling.

Research Project Title: Ion-conducting oxide ceramics for better battery electrolytes

Faculty Advisor for Research: Prof. Tianyu Zhu (Materials Science and Engineering)

Project Location: Anderson, SC (The Advanced Materials Research Laboratory)

Teacher's Research Project: Lithium-ion batteries have become the cornerstone of energy storage solutions, extensively used in consumer electronics and electric vehicles. However, the path to further advancing this technology is lined with significant challenges. These include the need for higher energy density, enhanced cycle life, and improved safety measures to reduce risks during operation and charging. In this project, teachers (and their mentors), will explore ion-conductive ceramics as a novel class of solid-state materials for electrolytes, aiming to supplant the traditional liquid electrolytes. The team is expected to initiate the process by fabricating dense oxide ceramics, followed by electrochemical characterizations of the materials. A key challenge will be to maintain the structural integrity and control the morphology. Our primary goal is to deepen our understanding of how ceramic processing influences the microstructure of the electrolyte material for battery applications. Critical questions to be addressed include the impact of particle sizes, chemical compositions, and processing conditions on the overall performance?

Faculty Advisor for Research: Prof. Enrique Martinez-Saez (Mechanical Engineering)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: The final microstructure in a solidification process is controlled by the properties of the solid-liquid interface. In traditional alloys, segregation of alloying elements to the interface modifies the response of the system. In Multi-Principal Element Alloys (MPEAs) the partitioning of the elements between the solid and liquid phases and the interface is not well understood. Such partitioning will in turn dictate the interface properties. Atomistic simulations combined with Monte Carlo (MC) methods will be used to understand the above-mentioned partitioning and how composition affects the interface properties, which will be calculated under different composition and temperature conditions. These parameters can be used in larger scale modeling methods to study the resulting morphologies depending on solidification conditions.

Research Project Title: Mechanical Characterization of Multi-Principle Element Alloys

Faculty Advisor for Research: Prof. Garrett Pataky (Mechanical Engineering)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: Multi-principle element alloys (MPEAs) are a new class of alloys developed in 2004 which removed the traditional alloy development methodology of using a base element. The research interest in MPEAs has grown exponentially due to a number of promising properties identified thus far including high fracture toughness, high wear resistance, high hardness, and good corrosion resistance. Originally, the main alloys examined were equimolar, such as the Cantor alloy ($Cr_{20}Co_{20}Fe_{20}Ni_{20}Mn_{20}$), but recent research has combined the MPEA alloying technique with classical techniques to produce alloys with desirable traits. The push for higher performing alloys has led to the creation of several subclasses of MPEAs. The particular goal for this project will be to experimentally characterize the microstructure and mechanical properties of novel lightweight MPEAs.

Research Project Title: Laser 3D Printing of Highly Compacted Ceramic Energy Devices

Faculty Advisor for Research: Prof. Jianhua 'Joshua' Tong (Materials Science and Engineering)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: Laser 3D printing (L3DP) implies layer-by-layer shaping and rapid in-situ consolidating feedstock, typically polymer solution or metal powder, to arbitrarily complicated configurations by combining computer-controlled laser processing and computer-aided design (CAD). Current successful application of L3DP focuses on producing complex-shaped plastic and metallic prototypes, parts, and final products. Attempts to use L3DP for processing ceramics, however, have not been equally successful despite the great effort. Either the use of laser processing to densify ceramic electrolytes or the use of ink-jet printing to deposit electrode and electrolyte precursor films has been attempted for ceramic electrochemical devices. The low fluidizability of ceramic films, the low resistance to thermal stress, and the inevitable sizeable thermal gradient usually result in the formation of a large number of cracks. There has been no ceramic electrochemical device successfully fabricated by L3DP because of the cracks formed during laser processing.

Research Project Title: Human Integration to Assembly Processes

Faculty Advisor for Research: Prof. Laine Mears (Automotive Engineering)

Project Location: Greenville, SC (International Center for Automotive Research)

Teacher's Research Project: The teacher will contribute to on-going research on the integration of human behaviors to the smart and digital manufacturing environment. Specifically, the teacher will investigate how humans in manufacturing environments generate and use data and how their data can be merged with that of manufacturing equipment and software systems. This data set can then be leveraged to improve worker perceptions and the output quality of manufacturing. The teacher will work with Prof. Mears, an expert in advanced manufacturing, and his existing collaborators in the field of Learning Science and Psychology. The focus of the first summer will be to create data sets for (1) a machine generated data set and (2) a data set merged from both human-generated and machine-generated data.

Research Project Title: Mechanical Behavior of Tessellated Bistable Structures

Faculty Advisor for Research: Prof. Oliver Myers (Mechanical Engineering)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: The objective of this study is to achieve various shapes in multiple stable states of any given geometry, by using a combination of traditional and bistable composite laminate structures. Bistable composite laminates have proven useful for shape changing structures. These structures have been useful for unmanned aerial systems as morphing wings that change the flight dynamics and behavior of the UAS. Most of these bistable structures are fabricated manually and integrated as a secondary process. Current research looks to fabricate and implement bistable structures in an integrated system. Non-traditional shapes of composite laminates (triangles, circles, octagons, etc.) which behave vastly differently than rectangular structures when they are present in a multiple connected form will also be integrated into a morphing system.

The teacher will be trained in the fabrication of bistable composite laminates. The teacher will implement fabrication methods to fabricate structures that potentially meet the design protocols and conduct experiments to determine load capacities and deformation profiles. The teacher will meet weekly with the PI to (1) share research progress and challenges; (2) formulate continuing progressions and (3) participate PI's research group meetings for research discussions and manuscript preparations. Suggested Teacher Expertise: This project would be of interest to high school teachers who facilitate laboratory science courses (physics or introduction to engineering), mathematical sciences (algebra I or 2, pre-calculus, calculus). In addition, it would interest community college instructors teaching EGR 269 'Engineering Disciplines and Skills' or EGR 270 'Introduction to Engineering', both of which transfer into the Clemson General Engineering program.

Research Project Title: Approaches to Visualizing and Understanding Energy-Use in Metals Production

Faculty Advisor for Research: Prof. Mark Johnson (Clemson Center for Advanced Manufacturing)

Project Location: Greenville, SC (International Center for Automotive Research)

Teacher's Research Project: Metal production requires the application of energy to raw materials, from reduction of ore to the fabrication and assembly of processed metal into manufactured products. This represents nearly 20% of all energy used in manufacturing and is a significant source of energy related emissions. This societal challenge motivates significant scientific research along three general pathways: (a) investigation of new materials with appropriate properties with lower embodied energy (circularity), (b) exploration of sensor based cyber-physical systems to minimize the energy use in manufacturing processes (i.e., smart manufacturing) and (c) investigation of new processes (additive) to use material resource efficiency and reduce embodied energy loss in scrap. While significant research has focused on foundational materials and information science, there has been less work at exploring or quantifying the underlying assumptions of energy use in the production or use of metallic structures. Understanding the scale and nature of energy in materials manufacturing inhibits realization of manufacturable solutions.

Research Project Title: Data science coupled with computational materials science for the design new alloys

Faculty Advisor for Research: Prof. Dilpuneet 'DP' Aidhy (Department of Materials Science and Engineering)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: The presence of multiple elements in large proportions in multi-principal element alloys (MPEAs) opens a vast compositional phase space with exciting materials design opportunities. However, it also presents a large computational challenge to the design and discovery of materials, especially for density functional theory (DFT), which has traditionally been highly successful in the design of conventional/dilute materials. Additionally, the random presence of chemically-different elements on a crystal lattice presents rich physics but also creates electronic and lattice distortions essentially at each lattice site thereby creating additional challenge to understand the mechanisms that lead to the exciting properties. In this proposal, we will couple data science with DFT to learn atomic level patterns for predicting properties in MPEAs thereby overcoming the computational challenge of large phase space.

Research Project Title: Fabrication, Functionalization, and Testing of Chronic Wound Biosensors

Faculty Advisor for Research: Prof. Jordon Gilmore (Bioengineering)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: The evaluation of chronic wounds, particularly in diabetic or otherwise immunocompromised patients is currently performed by a broad-spectrum of healthcare providers (e.g., home health nurses to vascular surgeons), making the process highly subjective and variable based on clinician expertise and experience. The goal of this project is to develop a biosensor capable of providing quantitative feedback of wound healing progression in chronic non-healing wounds. The biosensor consist of a combination of biocompatible elements, including a knitted poly-l-lactide biotextile base layer, screen printed Silver (Ag) ink layer, and solution blow spun (SBS) multi-walled Carbon nano-tubes (MWCNT), all having been demonstrated as safe in short topical exposures such as presented here (except for individuals with silver allergies). Using a modified Enzyme-linked Immunosorbent Assay (ELISA), we will functionalize the nanofiber composite biosensor surface to provide quantitative assessment of the following inflammatory markers related to various stages of wound healing: transforming growth factor – beta (TGF-β), tissue necrosis factor – alpha (TNF-α), and vascular endothelial growth factor (VEGF). TNF-alpha, commonly associated with the pro-inflammatory M1 macrophage phenotype, will be measured against TGF-beta (anti-inflammatory, associated with proliferation phase of wound healing and M2 macrophage phenotype) and VEGF (associated with angiogenesis). Each biomarker (TGF-beta, TNF-alpha, and VEGF) measurement will be normalized using a control (non-functionalized) sensor that will characterize the general electrochemical impedance response to the wound bed. Sensors will be tested both in vitro and in vivo as a part of a small ongoing clinical trial at Prisma Health Upstate - Oconee Memorial Wound Care and Hyperbaric Medicine Center.

Research Project Title: Elucidating the connection between Tribological Performance of 316 and 304 Stainless Steel with and without Femtosecond-laser Shock Peening Surface Processing

Faculty Advisor for Research: Prof. X. Zhao (Mechanical Engineering)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: 304 and 316 stainless steel (304/316SS) are similar materials known for their high strength and corrosion resistance. They are used for a multitude of biomedical and aerospace applications, due to their tolerance of aggressive environments. Considering the expanding applications of 304/316 SS, researchers are investigating surface treatments to improve their mechanical properties. Benedetti, et al. investigated a method called shot peening to prolong the fatigue life of Ti-6Al-4V ELI samples prepared with Selective Laser Melting (SLM). They discovered that shot peening is a cost-effective method for increasing the life of their samples.[3] Shot peening is a method of adding compressive stress to the surface of a material to prevent crack initiation. However, this method tends to affect the surface morphology of materials negatively and has been replaced in many instances by laser shock peening (LSP).[4] Li, et al. established that femtosecond laser shock peening (FLSP) presents the opportunity to improve fatigue life, hardness, and strength of materials like 304SS. The teacher will investigate the wear behavior of 304SS that has undergone laser shock peening surface treatment compared to as-received 304 SS.

Research Project Title: Simulation of Warehouse Operations

Faculty Advisor for Research: Prof. Mary Beth Kurz (Industrial Engineering)

Project Location: Clemson, SC (Main Campus)

Teacher's Research Project: Almost every store from which people get items – online or brick-and-mortar – has some sort of inventory. Sometimes, it is on shelves, while other times, it is in some sort of "back-room" or warehouse. Even places like libraries and post offices can be considered warehouses of some sort. Operating these warehouses efficiently helps companies – large and small – operate more profitably. With the Siemens Plant Simulation software and Clemson's access to the online training modules, we will model one or more local facilities.

Research Project Title: Modernizing South Carolina Manufacturing Assets to Enable Industry 4.0

Faculty Advisor for Research: Prof. Saeed Farahani (Automotive Engineering)

Project Location: Greenville, SC (International Center for Automotive Research)

Teacher's Research Project: The teacher will contribute to on-going research on modernizing legacy manufacturing processes, with a focus on tools that enable implementation of Industry 4.0 in existing manufacturing facilities. Industry 4.0 is a term used to describe the evolution of traditional manufacturing and industrial practices through the integration of digital technologies, data exchange, and automation, with an overall goal of creating "Smart Factories" that enable more efficient, flexible, and customized production processes. Specifically, the teacher will participate in investigating the technical challenges of developing standardized processes for modernizing production systems, independent of equipment type or manufacturing process. This research will be leveraged to improve South Carolina factories, leading to a variety of economic and environmental benefits such as creating more competitive production output, consuming fewer resources, extending the life cycles of equipment, and improving safety for workers in industrial environments. The teacher will work with Prof. Farahani, an expert in smart manufacturing, his research Team, and industry collaborators. This research opportunity will provide valuable insight into an emerging and technologically innovative local industry and will help the teacher prepare their students for a growing job market in South Carolina.

Suggested Teacher Expertise: This project would be of interest to high school teachers who facilitate laboratory science courses (engineering, science, or chemistry), mathematical sciences (algebra I or 2, pre-calculus, calculus). In addition, it would interest community college instructors teaching EGR 269

‘Engineering Disciplines and Skills’ or EGR 270 ‘Introduction to Engineering’, both of which transfer into the Clemson General Engineering program.