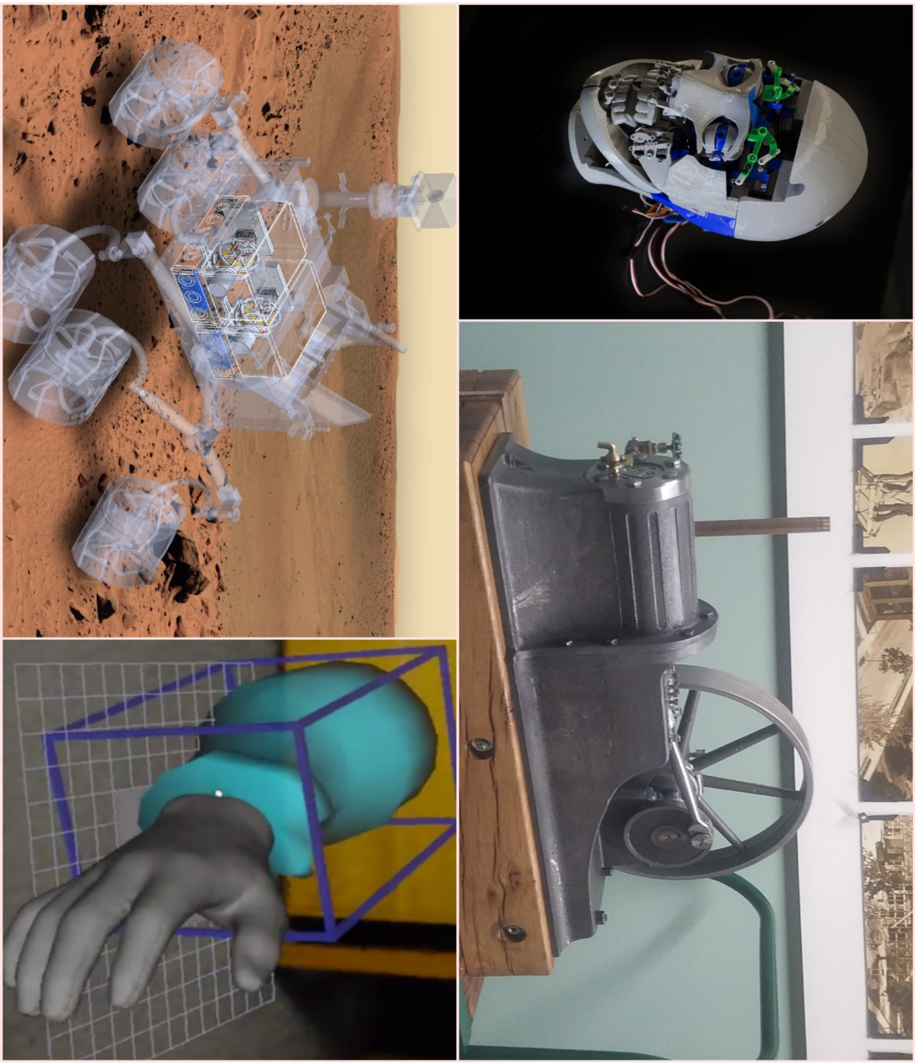
Worcester Polytechnic Institute

Mechanical Engineering Department



Project Presentation Day

April 19, 2019

Schedule for Project Presentation Day
Mechanical Engineering Department
April 19, 2019

8:00 AM	Judges Assemble	Higgins Labs 102
8:00 - 8:30 AM	<u>Breakfast</u>	
	Judges	Higgins Labs 102
	Students	Alden Hall
8:15 - 8:30 AM	Judges Instructions	Higgins Labs 102
8:30 - 11:30 PM	Presentations	Alden Hall
12:00 - 1:00 PM	<u>Lunch</u>	
	Judges	Higgins Labs 102
	Students	Alden Hall
1:00 - 1:15 PM	Winners Announced	Alden Hall

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Biomechanical

Functional Analysis of an Ankle-Foot Orthosis: The Intrepid Dynamic Exoskeletal Orthosis (IDEO)

Andrew Lucy

Lower limb injuries that impact a patient's ability to walk can also lead to pain in the knees, back, and hips. This project investigated the functionality of an ankle-foot orthosis known as the Intrepid Dynamic Exoskeletal Orthosis (IDEO) that attempts to salvage injured limbs using basic principles of biomechanics. With the help of the designer of the device, a patient that uses the device, and many others, the team studied the function of the IDEO in order to model its ability to transfer energy to the affected limb and restore normal gait function to the patient. We found that the IDEO stores energy while the patient walks using favorable material properties to replace the function of injured parts of the body. In addition, the device provides substantial support at the knee during the stance phase of the gait cycle. Further development in the modelling of joint reactions should be explored to assist in the evolution of similar medical devices.

Advisor: Holly Ault

Biomechanical

Load Absorption Device for Ice Hockey Shoulder Pads

Benjamin Aldrich, Matthew Moore, Kathryn O'Donnell, Andrea Rota

In contact sports, especially hockey, players experience upper extremity injuries from collisions during play. The loads associated with these collisions can tear the ligaments that stabilize the acromioclavicular (AC) joint, causing shoulder separation. Current technology uses a combination of foams and plastics as a barrier between the load and the AC joint. Using axiomatic design, the team designed a device integrated into a shoulder pad to dissipate injurious loads to areas around the AC joint. Although the team observed the effectiveness of the device through validation testing, additional testing to understand how the loads are dissipated throughout the device and around the shoulder is recommended.

Advisors: Christopher Brown, Tiffiny Butler (BME)

Biomechanical

Preventative Care Knee Exoskeleton

Steven Franca, Ariel Goldner, Stephanie Marcucci,
Matthew Schueler, Daniel Wivagg

The increasing aging population frequently suffers from knee joint degeneration. This demographic has limited access to preventative injury solutions due to the high costs of medical devices, thus impacting range of motion, independence, and safety. Assistive exoskeletons are widely known as a solution to combat pain occurring in mobility tasks. Typically, these devices are designed for a general population and then fit for each patient. In response, this project aimed to develop a low cost, customizable assistive knee exoskeleton for increased quality of life. We developed software to use 3D scans to create models of the patient's leg. These models were used to set the parameters of 3D printed parts for a patient specific exoskeleton. The device also has an actively powered component which provides assistance during the gait cycle. Effectiveness was measured by conducting a gait analysis with and without the device to determine how well the device fit and how well it followed the wearer's gait.

Advisors: Loris Fichera (CS), Gregory Fischer

Biomechanical

Investigation of UCL Tears in Baseball Pitchers

Maddie Brennan, Steven Gallagher, Benedict Kurtze, Paula Sardi

Tearing of the ulnar collateral ligament (UCL) is one of the most common injuries for baseball pitchers. During a pitch, the UCL experiences high levels of stress between the cocking and acceleration phase due to a valgus moment. Because this stress cannot be directly measured in vivo, a pitching robot with numerous biomimetic features was created to gain a better understanding of these forces during a fastball pitch. This robotic research platform was then used to design a brace that reduces the amount of stress the ligament undergoes, prolonging the play time for athletes. The robotic arm in the form of a human skeletal replica features seven independently pneumatically actuated Hydro Muscles and a biomimetic UCL. The effectiveness of the brace was validated by interfacing it with the robotic arm and measuring the forces on the artificial UCL throughout the pitching phases.

Advisors: Selcuk Guceri, Marko Popovic (PH)

Biomechanical

Soft Ankle Exosuit for Correction of Foot Drop

Joshua Galang, Lauren Morgan-Evans, Hannah Yeung

Foot drop is a common condition caused by nerve damage, muscular dystrophy, as well as brain and spinal cord disorders and characterized by a difficulty to perform dorsiflexion: the inability to lift the front part of the foot, resulting in a dragging foot. Causes include slow walking speed, inefficient gait, balance problems, and the inability to position the foot and heel strike. Although many people suffer from this condition, there is no actively powered brace on the market. This project introduces a wearable, actively powered device that can be worn beneath regular clothing. The device uses force sensitive resistors (FSR) to deduce the gait phase, and an ultrasonic sensor deduces ground conditions such as obstacles, inclines, and stairs. A lightweight and compact servo motor placed next to the knee joint actuates the ankle joint through a Bowden cable.

Advisors: Selcuk Guceri, Marko Popovic (PH)

Biomechanical

Impact Absorbing Wrist Guard for Snowboarders

Cole Godzinski, Marc LaBahn, Hannah Modelski, Kyle Whittaker

Snowboarding has become an increasingly popular winter sport. This rise in popularity has resulted in a higher number of wrist injuries due to the tendency of snowboarders to fall with outstretched hands. Commercially available wrist guards are restrictive, bulky and simply transfer the impact force away from the wrist to the forearm and elbow. Consequently, many snowboarders do not wear wrist guards. The goal of this project was to increase use of wrist protective equipment and decrease wrist fractures by creating a low profile, non-restrictive design with superior impact absorption capabilities. The final prototype incorporated removable individual cells of a shear-thickening polymer in an all-in-one protective winter glove liner. The flexible and slim-fitting design increased the comfort of the user. Drop weight impact testing demonstrated energy absorption in a simulated fall of 61-68% within a temperature range of -4 to 68 degrees Fahrenheit.

Advisor: Fiona Levey

Biomechanical

Fiber Optical Tweezers for Brain Property Measurements

Li-Yang Chiang, Matthew DeBenedictis, Qindong Zhang

Traumatic brain injury (TBI) affects nearly ten million people globally per year and is largely linked to sporting accidents. Knowing mechanical properties of brain tissues is imperative to diagnosis and prevention of TBIs. Yet, past and current methods yield a wide spectrum of brain tissue stiffness measurements with no clear convergence. Fiber optical tweezers (FOTs) have the potential to bridge this gap. Optical tweezers (OTs) are a Nobel-Prize-winning technique routinely used in various biomechanics studies, but have not been used for brain measurements due to its bulky size. As the next generation of OTs, the FOTs are small, modular tools capable of trapping microspheres via laser illumination, allowing for mechanical interrogation of the local medium. The team fabricated the FOTs to realize brain white matter stiffness measurements, which are comparable to those seen in literature. This work can find potential applications in understanding TBI and designing sports equipment.

Advisor: Yuxiang Liu

Sponsor: National Science Foundation

Biomechanical

Attachable Arm Bike for Alternative Wheelchair Propulsion

Heather Bourassa, Kylie Juarez, Erin McCann, Zoe Schwartz, Caraline Wood

Current options for alternative wheelchair propulsion devices are cumbersome, expensive, and dangerous if transfer from wheelchair to another device is required. Devices with chains are unreliable due to chain breakage or derailment. To combat these shortcomings, this project created a gear and drive shaft powered, attachable arm bike prototype. This project validates the concept of a chainless arm bike and lays the groundwork for further products that are more compact and less expensive than existing models.

Advisor: Brian Savilonis

Biomechanical

Evaluating Performance Testing Procedures for Baseball Catcher's Helmets

Sophia Gervasio, Derek Kruzan, Walter Kwiecinski,
Ryan McLaughlin

Collisions between a baseball bat and a catcher's helmet is a rare, yet severe impact that often leads to head and brain injuries. Catcher's helmets are currently designed to pass NOCSAE standards in a linear drop test. A testing apparatus that replicates a batter's backswing was prototyped to incorporate angular acceleration and tested by colliding a baseball bat into a headform. Testing was performed at six velocities between 11 and 25 mph with and without helmet protection. Peak G and Severity Index were measured at the headform's center of mass to demonstrate collision effects at the brain. Collected data validated existing drop test for 1D testing but suggests NOCSAE standards may test unrealistically high energy impacts. Risk of injury decreased significantly when a helmet covered the headform and is explained through a viscoelastic model. Future modifications in helmet designs and testing procedures will likely incorporate angular acceleration to improve the three-dimensional reaction models of the brain.

Advisor: Brian Savilonis

Design

Assistive Guitar Plucking Device and User Interface

Daniel Farnitano, Laurèl Higham, Victoria Mercouris, Benjamin Shaffer

The goal of the project was to develop a device that would enable individuals with physical disabilities to play a guitar. The device includes a plucking mechanism and a wearable user interface, to be used in conjunction with a guitar fretting device built by the project sponsor, Kurt Coble. The plucking mechanism, mounted to an adjustable frame around the guitar, has 3D printed plectra to actuate each guitar string, driven by servo motors. The inertial measurement unit based user interface is comprised of two wearable devices that calculate which strings to pluck, by using sensor fusion to track user motion and device orientation. Both devices are wireless and battery-powered, allowing for convenient use in a variety of settings. Music provides people an avenue to express their emotions and has been shown to stimulate the brain in uniquely beneficial ways. This project provides an opportunity to create music for individuals who have not previously had access to this experience.

Advisors: Curtis Abel (UG), Holly Ault

Sponsor: PAM Band

Design

Design and Analysis of Packaging Methods at PepsiCo Frito-Lay

David Bovich, Lillian Olsen, Nathan Pietrowicz, Benjamin Seitz

The objective of this MQP was to design a solution to address the ergonomic issues and increase sanitation during transportation of a key production line component known as a 'former'.
The rationale was to reduce time during production line changeover and minimize wear and tear on food packaging equipment.

Some of the methods included axiomatic design, value stream mapping, and SolidWorks 3D modeling software to design the cart, as well as operator feedback sessions to receive criticism on the cart iterations.

Our results included a re-designed transportation cart being prototyped as well as comments about implementing and airlift.
In conclusion, we designed an improvement to streamline a design for the company and save about 8% of time on the changeover, yielding about $150,000 annually.

Advisors: Torbjorn Bergstrom, Walter Towner Jr. (IE),
Helen Vassallo (IE)

Design

Stylus for Fine-Motor Development

Nathan Rose, Tom Ward, Shane Whittaker

The objective of this project was to improve the writing skills of children by designing a stylus that encourages the development of fine motor ability. This objective was inspired by a day care owner, one of our relatives, asserting that there is a marked decline in the writing ability of children (a claim which our research would corroborate). We started with a prototype based on literature on child motor development, which included academic research as well as practical advice from occupational therapists. We concluded that the grip of our stylus should be shaped to help children develop the strength and coordination for the typical final stage of hand writing development: the “Dynamic Tripod” grasp, which is usually the most difficult transition for children. To refine our initial design, we repeated a process of prototyping (using the Fitzgerald Prototyping Lab for quick turnaround), field testing with children, and interviews child care professionals. From this process we settled on two designs: one for aided individual development and the other for general, unmonitored classroom usage.

Advisor: Torbjorn Bergstrom

Design

Design of a Multi Laser System

Matthew Lund

Helium balloon releases have been a mainstay at celebratory events. However, balloons can travel hundreds of miles and have a tendency to end up in lakes, seas and oceans. These bodies of water are vulnerable because balloons pose a danger to aquatic life and have a significant impact on pollution levels. Clean up efforts have found tens of thousands of balloons on beaches yearly in the United States alone (Witmer, 2017)*. Laser light can be used to damage balloon's membranes and prohibit them from flying into bodies of water. This project explores the usage of a system of links and slides to target and safely remove balloons from the atmosphere using laser light. Theoretically, the linkage-laser system offers ranges of a few miles, but the current system is limited due to Gaussian beam and power limitations. Future work can be extended to auto-detect and target the balloons in the air.

Advisors: Mehul Bhatia, Rudra Kafle (PH)

- Witmer, V. (2017, November). Balloon Release Research in Virginia & Reducing Balloon Debris through Community-Based Social Marketing. Retrieved March 22, 2019

Design

Increasing the Throughput of 3D Printers with Automated Part Removal

Muhammad Hussain, Brian King, Chris Kirven, Brian Sayers, Benjamin Secino, Baron Strasburger

Rapid prototyping is gaining popularity through the increased availability of highly capable, low-cost 3D printers. The standard operating procedure for 3D printing requires the user to upload the G-code of the part to the 3D printer to initiate the production process. Upon completion, the user returns to the printer and manually removes the part. In the event the user delays their return to the machine, the part remains on the print bed waiting to be removed, thereby increasing the machine's non-value-added time. In order to eliminate this idle time, a new add-on system has been developed through this project to automatically remove a part from the print bed. The removal process occurs within a few seconds of print completion. This allows for subsequent parts to be printed without waiting for the user to return to the printer. The design utilizes a blade that glides across the print bed, slicing the part off and removing it from the bed. This motion is achieved through vertical and horizontal actuators working in tandem to place the blade on the bed, scrape off the part, and home the blade out of the printer's workspace. Actuator motion is controlled with limit switches and a quadrature encoder. The machine is modular and able to fit several models of open-air 3D printers. The removal of several parts has been successfully tested. Further details about the design process, the prototype, and the various tests carried out on the machine will be presented.

Advisors: Mehul Bhatia, Pradeep Radhakrishnan

Design

Edge Design for Performance

Evan Bossio, Sophia Leitzman, Riley Lopez, Amanda Rodriguez

This project examines the relationship between knife surface features and food sticking to the side of the blade. Since no existing literature was found on the subject, we developed original blade designs and testing procedures. Our designs focused on limiting potential contact area by pushing food away from the blade. After testing 5 different knives, we found that the curved chip-breaker design resulted in the best performance.

Advisor: Christopher Brown

Design

Head Injury Prevention - Helmet

Josh Herlands, Austin Lindner and Douglas Rives

Concussions are a prominent issue within most sports. Our project focuses on creating a catcher's helmet that will reduce head injuries and keep athletes safe. Our design replaces the foam used in current helmets with nonlinear springs attached to the face cage as well as nonlinear springs within the helmet itself. These changes allow for greater displacement of the impact on the helmet, and therefore by the work-energy theorem, greater force is absorbed by the helmet as opposed to the athlete’s head. On the exterior of the helmet, we explored different materials of the shell and coatings that would reduce the overall weight and torsional forces. This helmet is promising for reducing head injuries and keeping athletes safe, without impacting performance.

Advisor: Christopher Brown

Design

Sit Ski by Axiomatic Design

Jared Grier, Austin McCalmont, David Parker, Jeffrey St. Hilaire

Current adaptive skiing devices, such as monoskis and biskis, fail to provide many of the controls that non-disabled skiers have such as fore-aft movement of CG, edge angle, and vertical articulation of skis. Due to these limitations it can be difficult to satisfy Euler's equations for stability in 3-D and thereby exit turns cleanly (Brown and LeMaster 2012). This project creates an adaptive skiing device that can better replicate normal skiing techniques which may enable better skiing and lessen the strength and balance demands required to operate the ski. A rigorous, structured innovation process following axiomatic design (AD) theory and methods is used to develop viable solutions. AD theory states that all good design solutions must comply with two axioms: maintain the independence of the functional elements and minimize the information content. Following this design theory, we have come to a solution that can better replicate a non-disabled skier with independent fore-aft, lateral-medial, vertical, edging, and steering of each ski. A prototype is in production.

Advisor: Christopher Brown

Sponsor: Robert Neumeister

Design

Ski Binding Design Suspension System for Vertical Load Transmission

Madison Healey, Matthew Newell, Kendra O'Malley, Connor O'Neill

A ski binding suspension system was studied and designed to reduce anterior cruciate ligament, tibial plateau, and back injuries and avoid inadvertent heel release, by absorbing vertical loads and fore-aft torques. Conventional bindings do not protect against these injuries, which can be expensive and keep people from skiing. Axiomatic design was used to develop a solution by simultaneous decomposition from abstract to detailed functional and physical domains. A plate system was designed to reduce the vertical loads while skiing. The system is supported by nonlinear springs to absorb shocks and vibrations between the boot and the hard snow surface. It changes the natural frequency of the system to ease the dynamic loading on the tibia and back. When a load exceeds ordinary skiing loads, the system displaces to absorb some of the load through the springs, increasing the time the skier has to recover from the injurious loads.

Advisor: Christopher Brown

Design

Correcting Errors and Adding Features to PMKS

Mitchell Farren, Alexander Galvan, Albert Nana Beka,
David Richardson, Zhihao Xie

The Planar Mechanism Kinematic Simulator (PMKS) is a web-based tool to generate the kinematics of linkages. The tool can also be used to generate joint forces and input torque in linkages with revolute joints. Stress analysis of links and joints can also be carried out. While the mathematical formulation related to the kinematics, statics and kinetics is accurate, there are errors related to the various units and their conversion in the underlying code. Therefore, one of the first project activity was to identify and correct these errors in mass, volume, mass moment of inertia, force, and stress calculations. After this, the team considered various additions to the tool. These included formulating mass properties for different link geometries, determining equations for static and dynamic analysis of slider crank linkages, and implementing methods to detect singularities in four and six-bar linkages with revolute joints. The team also worked on generating interface concepts for displaying free body diagrams and simulator results to enhance student experience with the tool. In addition, aspects of the migration of the tool from the current Microsoft Silverlight platform to the Microsoft Windows Desktop were also investigated.

Advisors: David Brown (CS), Pradeep Radhakrishnan

Design

Developing a Device to Place Traffic Cones

Christopher Ferreira, Holly Gagnon, Zachary Whitmore

The goal of this project was to create a device to place traffic cones. Conventional methods of traffic cone placement are dangerous and inefficient, so this design aims to improve road workers' safety and use of time. The design uses a fourbar linkage, pulley system, and specially designed gripper, which work together in a cyclical motion to remove cones from a stack and place them alongside a moving vehicle. Our team fabricated this device using stock metal and robotic parts. After testing, we created recommendations for further development.

Advisor: Eben Cobb

Design

Human Powered Recreation Vehicle

Nolan Bell, Alexander Gallant, Michael Munroe,
Katherine Schweikert

The motivation for this project was to design and build a human powered vehicle for the main purpose of recreation. The target clients for the project are adult victims of stroke who now suffer from hemiparesis. After researching the current market and resources for recreation, the team developed four preliminary concepts, used a morph chart to select the best features from each, and designed a final prototype. The prototype was built using the frame from a Mobo Trike incorporating modifications such that the tricycle is operated with the right side of the body exclusively. The final prototype meets all functional requirements outlined at the start of the project.

Advisor: Eben Cobb

Design

Pool Chair Lift

Amanda Alves, David Cadilek, Daniel Corwin

This project was created to improve existing technology and create a design for a new chair lift to assist the disabled in entering and exiting a pool. Our goal was achieved through in-depth research into the problems within technology already on the market, and creating a proposal that improved on the portability weakness most designs possess. Initial concepts were analyzed to determine the lift mechanism and counterweight system for the device. Once a design was chosen, we completed a full CAD model of the device and all of its subassemblies to show and test basic functionality. After the model was complete, we then bought all the components of the device and began manufacturing, using the tools available in Washburn Shops. Finally, construction progress and a list of future recommendations was presented to our advisor for further implementation and utilization.

Advisor: Eben Cobb

Design

Redesigning the Posterior Pediatric Walker

Julia Decker, Ryan Foley, Kelly McMahon, Victoria Nassar

Cerebral Palsy is a disease that impacts the motor functions of an individual, often limiting individual's ability to walk. Assistive walking devices are available to aid children with cerebral palsy in walking including posterior walkers and gait trainers. However, these devices often limit users socially, restrict their mobility, and can be difficult to maneuver. Posterior walkers can also be very difficult to collapse and adjust, making transporting the walkers very difficult. Further, walkers for children often need to be replaced due to how quickly children grow. This project aims to create a design that solves these issues and assists the user in walking with proper posture. Through research and several interviews with a family and a pediatric physical therapist that have experience with posterior walkers, a three wheeled posterior walker with a unique hinging mechanism was designed using SolidWorks. The walker built according to the selected design is adaptable, user friendly, and aesthetically appealing allowing children with cerebral palsy, ages two to eight, to develop physically and socially.

Advisor : Eben Cobb

Design

Retractable Traction System

Kaitlyn DaSilva, Karen Mushrall, and Martin Walwik

Pedestrians in urban New England face dangerously icy conditions which create a slipping hazard and can lead to serious injury. One way to reduce this hazard is through footwear traction systems. There are several products on the market, such as crampons and ice cleats, but they are cumbersome and inconvenient because they are removable devices that should only be worn on frozen surfaces. This forces users to attach or remove the system with every surface change. Conversely, a retractable traction system streamlines the transition between dry pavement, icy pavement, and indoor flooring. This project introduces such a system through a scale prototype of a modular half-shoe retractable spike mechanism.

Advisor: Eben Cobb

Design

Recreating Steam Power at WPI

Michael Cooke, Thomas Kouttron

Steam power made possible the early growth and success of WPI as an Institution. Beginning in the late 1800's three large stationary Steam Engines were used to power all of the equipment in the Washburn Shops and provide auxiliary electricity before municipal electrification. Researching original archive photos of the WPI Powerhouse sparked an interest in steam engine technology, the group launched a plan to design, manufacture and construct a 1/5 scale model of the original, Fitchburg-built Putnam Steam Engine, using modern manufacturing practices to recreate the engine in period correct materials. The engine was recreated without original drawings, working only from photos, period books and scaling of original design to ensure that the engine would function properly at a smaller scale. Period correct materials and casting processes were researched to ensure that all components would perform properly and to identify suitable, cost effective modern manufacturing techniques. Major engine components were cast from wood patterns made in the Higgins Labs shop. Various manual and CNC machining techniques were employed. Work commenced in August to build a running scale engine, which was completed and ready for testing in late March. Performance of the finished engine will be discussed. Overall the knowledge gained from completing this engine covers many fields of mechanical engineering and demonstrates the fundamentals of WPI's motto Theory and Practice.

Advisor: Robert Daniello

Design

Design and Validation of a Novel Mission Framework for the Detumbling of Rotating Space Debris Using a Tether-Net Linkage and Momentum Wheel

Josh Desmond, Max Luu, Timothy Stump

Space debris in low Earth orbit (LEO) is a growing concern for the future of space travel and current satellite use. As the number of artificial satellites in LEO increases, the probability of collisions between these artificial satellites increases, and so does the need for cost-effective space debris remediation. A mission framework for the capture and de-tumbling of space debris was designed and tested. A computer simulation was used to observe the contact dynamics of a net on space debris and its efficacy in capturing tumbling satellites. An experiment was designed to validate the use of a momentum wheel and tether-net linkage to detumble spinning space debris.

Advisors: Frank Dick (PH), Zhikun Hou, Carlo Pinciroli (CS)

Design

Design and Optimization of a Formula SAE Vehicle

James Chakalos, Justin Dyer, Matthew Freed, Justin Harris, James Meagher

The 2019 FSAE vehicle is the culmination of an aggressive team effort to transition to a one year build cycle. The car is a bottom up refinement of the groundwork laid by the 2018 build team, with a heavy emphasis on improving drivability, power, and ergonomics without additional weight. The frame was completely redesigned to increase length and width in the driver compartment, significantly increasing comfort. The pedal assembly was redesigned to allow quick and simple adjustment for a wider range of driver heights. On the powertrain side, a new engine, piston, and intake design combined with more detailed engine modeling to meet our power goals. These changes, together with additional refinements to steering, shifting, and suspension, come together in a car that allows its driver to focus on what matters...going fast.

Advisors: Mustapha Fofana, John Hall, David Planchard

Application of VR to the Engineering Design Process

Ralph Grzybek, Gregory Pelland, Maricella Ramirez

As technology progresses faster with every innovation, design engineers are now able to go through the engineering design process with increased efficiency. With advancements in software engineering and the miniaturization of sensors and displays the resulting development of Virtual Reality technology allows users to explore and interact with a 3D computer generated environment. We hypothesize that recent and future improvements to Virtual Reality will allow engineers to apply this technology in all aspects of the design process. To prove this hypothesis, two case studies were conducted using Virtual Reality in all steps of the engineering design process. In the first case study, a methodology was created to include VR wherever possible for each step of the design process with the deliverable being an optimized design of a mechanical component. In this case, VR was applied to the steps of Background Research, Ideation and Analysis as well as assisting in all other steps. The second case study was developed towards designing custom devices for medical applications. In this case, we demonstrated the use of 3D Digitization and utilized VR as a mesh editing and visualization tool. Through these case studies we found that VR has the potential for wider application to the engineering design process, however, exciting and expected future developments on this and related technologies are still required.

Advisor: Cosme Furlong

Sponsor: WPI Academic & Research Computing

Design

Design, Realization, and Application of an Ultra-High-Speed Shock Tube for Middle-Ear Mechanics

Eli Frank, John Perkoski, Jacquelyn Roberge, Jessica Walsh

The Tympanic Membrane (TM) is an important middle-ear structure that is highly susceptible to trauma due to environmental changes and acoustic pressures, yet minimal investigations have been conducted on its fracture mechanics. WPI researchers, in collaboration with Massachusetts Eye and Ear, are conducting advanced research toward understanding the TM fracture mechanics in real-time by using 3D Quantitative High-Speed Optical techniques. In this project, we designed, constructed, and characterized an ultra-high-speed shock tube to produce controlled acoustic shock waves, enabling us to perform accurate and repeatable investigations on the mechanics of the TM at high loading rates. Rankine-Hugoniot relations and computational fluid dynamics were applied to design and predict the behavior of the apparatus, while a series of high-frequency pressure sensors were adapted into the system to record and confirm the computational results. High-speed cameras operating at >35,000fps were incorporated with Schlieren photography methods to image the density differentiation of the produced acoustic pressure waves. The developed apparatus and methods were validated through rupture tests on known samples, and finally applied to actual human TMs to study ear damage by high level sound.

Advisor: Cosme Furlong

Sponsor: Massachusetts Eye and Ear and Harvard Medical School
Jeffrey Tao Cheng, Ph.D., John J. Rosowski, Ph.D.

Design

Design and Assembly of Acetone Distillation System

Chase Arsenault, Olivia Baranowski, Nicholas Batchelder,
Tyler Costello

Acetone and other volatile solvents are often utilized in industrial applications. Acetone is mainly used for industrial cleaning when lab material is contaminated with undesired residue. After the acetone is used to clean lab equipment, often time's companies discard the solvents at a large expense. This project focuses on creating a small scale acetone distillation system to purify these contaminated solvents in order to reuse them. This paper will outline the research, design, and assembly of this system. The group assembled the contaminated acetone distillation system and provided recommendations for improvements to the system that can create a more efficient and commercialized distillation unit.

Advisor: Selcuk Guceri

Design

Design & Development of an Electric-Powered Hand Truck for In-Home Use

Azita Bakhtyari, Justin Nguyen, Ayushka Shrestha,
Timothy Tetreault

Currently, there is a lack of an in-home automatic lifting mechanism in the hand truck industry that is low in weight and cost. This project aimed to create an original design of an automatic hand truck, suitable for in-home use, particularly assisting the elderly or injured individuals with heavy lifting. The steps taken to achieve this goal included, calculating values necessary for proper operation of the product, creating a CAD model of the design, manufacturing a ⅔ scaled prototype of the design, testing the prototype, and proposing recommendations for full scale manufacturing. At the conclusion of the project, qualitative testing demonstrated that the ball screw assembly used within the hand truck operated successfully, providing a proof of concept for the lifting mechanism.

Advisor: Selcuk Guceri

Design

Design of an Outrunner Hydrokinetic Turbine

Jillian Chu, Alexander Kim, Joseph Pagliuca

This project involves the design of a novel coreless hydrokinetic turbine. The goal was to develop a power plant that could harvest energy from a river or tidal basin to meet the energy needs of remote regions. The hydraulic turbine was designed as a rotating tube with turbine blades extending inwards in contrast with a traditional design in which blades extend radially outwards from the axis of rotation. This turbine is enclosed in an outer casing, similar to that of a jet engine, which contains three generators driven by the turbine. Performance optimization was conducted through simulations using ANSYS Fluent. Blade profiles were refined using blade element momentum theory in MATLAB with airfoil characteristic data calculated in XFOIL. An operational small-scale prototype was built for concept demonstration through physical water tunnel tests. The deliverables include design specifications for a hydroelectric power plant capable of producing electricity to meet energy demands in remote regions.

Advisor: Selcuk Guceri

Design

Gyroscopic Stabilization for Uniaxial Rotational Hand Tremor

David Muse, Ian Sun, Alec Wehse

The goal of this project was to create a device to reduce the magnitude of hand tremors in individuals with Parkinson's disease or Essential Tremor. We focused primarily on tremors that caused the hand to rotate about a central oscillator parallel to the forearm. We utilized the physical properties of a spinning gyroscope to act as the stabilization mechanism and dampen the tremor effects experienced by the individual. After several design iterations and mathematical models, our final prototype uses a small electric brushless motor to spin the gyroscope on a swinging cradle, which in turn is mounted to the base mount. This allows the gyroscope to naturally process due to an input torque and generate a counter torque along the axis of the hand's rotation. To monitor the device, we incorporated an RPM and gyroscopic sensor in conjunction with an Arduino to receive sensory information about the motion of the hand and gyroscope.

Advisors: John Hall, David Planchard

Design

3D Printing Material Analysis

Sean Cody, Peter Pham, Kyle Tyler, Jianqing Zhu

This project researched and developed a new testing method to analyze the young's modulus of 3D printed test specimens. Our group created a testing apparatus that would hold our cantilever beam test specimens. The beams were put under various weighted loads and the deflection was measured to calculate their young's modulus. In our 3D prints we display variation in strength with minor variable changes such as print orientation and different brands of 3D printers. A comparison is made of the various test specimens material strength when in theory there should be no difference. Our research compares material strength of our prints made based on standard printing settings from commercially available printers to known/expected values of the material.

Advisor: Zhikun Hou

Design

Train of Four Monitoring

Christopher Beauregard, Nicholas Bergstrom, Edward Crofts, Kyler Dillon, Anastasia Karapangou, Kinsey McNamara

The accurate assessment of muscle paralysis during anesthetization is important to prevent complications caused by improper administration of Neuromuscular Blocking Agents (NMBAs). The gold standard of assessment techniques is Train of Four Monitoring (TOF), but current objective measuring devices are limited to conditions in which the hand can move freely, forcing clinicians to subjectively measure responses by touch or sight. The goal of this project was to design, prototype, and test a device, which extends TOF technique to conditions where movement is restricted. Interviews were conducted with stakeholders, and university students were surveyed to get feedback on the preliminary designs. The resulting device consists of a thumb-mounted balloon, which converts the force due to thumb twitches into pressure, which then acts as the physical analog to muscle response. This pressure is transduced, and analyzed to produce a TOF count and TOF ratio. A prototype was constructed and tested on human subjects with different hand geometries. In conclusion, we accomplished our goal of designing, prototyping and testing a device to extend objective TOF to conditions where movement is restricted.

Advisors: Kwonmoo Lee (BME), Ahmet Sabuncu, Jeanine Skorinko (SSPS),

Design

Design and Development of a Football Neck Support and Testing Apparatus

Zachary Bellion, Sean Gillis, Francis Lubega,
Blayne Merchant, Colin Saunders

In the 2017 NFL football season, 291 players were diagnosed with a concussion. The goal of this project was to create a neck support for football players to reduce linear and rotational acceleration of the head, since these accelerations have been shown to lead to concussions. The prototype neck support was designed to be comfortable, unobtrusive, attach directly to the shoulder pads, and absorb as much impact energy as possible. To test the neck brace, a testing mechanism consisting of a pendulum impact tester and a test dummy were designed to replicate the size, weight, and impact force of a football player experiencing collisions to the head. Preliminary analysis of the data showed a reduction in linear acceleration of the head by 30% during impacts to the face mask, but did not reduce rotational acceleration when the helmet was impacted at 45 degrees from the center of the face.

Advisor: Fiona Levey

Design

Design of a Shoulder Pad to Reduce the Risk of Injury in Men's Lacrosse

Elianna Buckley, Juliana Cabello, Tristin Carlton, Gabriela Hoops

Many shoulder injuries occur as a result of player-to-player contact in collegiate men's lacrosse despite the required protective equipment mandated by the NCAA. There are currently no standards for lacrosse shoulder pads, and current shoulder pad designs do not provide sufficient coverage to the entire shoulder. We developed a design aimed to maximize both protection and mobility. Our prototype consisted of a dual-layer protection system encompassed in a compression layer to ensure snug fit during play. Impact tests were conducted using a pendulum testing rig, and comfort and mobility were assessed by surveying college lacrosse players. During an impact of 595 lbf (average force of a men's rugby shoulder tackle), our pad reduced the g-force experienced, while not limiting overhead and lateral range of motion.

Advisor: Fiona Levey

Design

SolFly: Solar Energy Tent Fly for Humanitarian Aid

Olivia Jones, Edward Noyes

The goal of this project was to develop a product which met the need for off-grid electricity production that is safe, transportable, and environmentally friendly. Displaced people have a particular need for off-grid energy. As a result, this project focuses on energy production for refugee camps. The proposed design utilizes thin film solar technology attached to a weather resistant nylon fabric on a rolling spring mechanism for ease of transportation and set up. This user-friendly device serves as a protective tent fly while producing solar electricity for tent inhabitants. The background research, stages of the design process, and testing conducted in order to develop a viable prototype are presented.

Advisor: Fiona Levey

Design

Realizing a Compact Neutron Beam Collimator for Neutron Radiography

Calvin Downey, Jessica Elder

Neutron imaging (NI) or neutron radiography (NR) is a radiographic testing technique used for non-destructive inspection applications across multiple scientific fields. In the current work, the main objective was to design, build, and analyze a compact neutron beam collimator, used in conjunction with an Adelphi D (d, n)He neutron generator. Designs were based on sourced Monte Carlo N-Particle (MCNP) parameter optimization, and were built using various machining techniques including water-jet cutting, laser cutting, and computer numerically controlled machining. With the realized collimator implemented into the system, the thermal neutron flux was examined, and the image resolution and required imaging time were quantitatively analyzed.

Advisors: David Medich (PH), Richard Sisson

Design

Designing Integrated Inputs for a Soft Robotic Mechatronic Tongue

Logan Chen

Oral cancer patients undergo invasive surgical procedures as a total glossectomy requiring the removal of the tongue, leaving patients with the inability to swallow, eat and speak. Current tongue prosthesis used for rehabilitation provide aesthetic and static functionality of the tongue, but do little in recreating the kinematic function of the original muscular organ.To improve the design of tongue prosthetic devices, a new miniaturized mechatronic tongue is being developed. This system consists of two parts, namely the tongue prosthesis and the actuation mechanism. This project focuses on generating concept designs for the actuation mechanism. The aim of these designs was ensuring adequate pressure propels fluid into the silicone tongue prosthesis to create synchronic movement. The concepts range from centrifugal air-pumps and linkages to camshafts, designs that can be miniaturized and embedded into the space available in a denture. Details of the various iterations and their effectiveness are discussed.

Advisor: Pradeep Radhakrishnan

Design

Flexible Solar Cell Test Fixture

Laura Bauer, Carl Turnquist, Alexandra Wallace

Flexible solar cells offer more versatile and diverse applications than traditional photovoltaics. In development, the structural and electrical integrity of the cells must be tested in response to mechanical stresses. This project aims to develop a fixture to test the effects of fatigue, bending at various radii, and stretching on flexible solar cell prototypes. The test fixture offers repeatable, consistent, and precise experiments to assess efficiencies and material responses in controlled environments. The design consists of a dry box for testing in different atmospheric conditions, a linear actuator to control and iterate bending radii, and an automation system for fatigue testing. A prototype was fabricated and tested with flexible solar cells to observe the effect of bending and fatigue.

Advisor: Pratap Rao

Design

Greenhouse Redesign for Elementary Educational Needs (GREEN)

Daniel Barra, Kathleen Nugent, Daniel Ottey, Adam Peternell, Jonathan Toomey, Sean Traynor

Learning and playing in nature help children develop important skills that later benefit them as adults. Turn Back Time Farm aims to create an environment where children interact with nature to facilitate development. The farm asked our team to design and construct a greenhouse to teach children the importance of sustainable farming and the intricacies of plant production. The goal of our project is to design and build a functional greenhouse for the Turn Back Time Farm.

The greenhouse is a hoop house made with bent steel pipes and glazed with 12mm thick polyethylene film. Our team designed the greenhouse based off heating, cooling, and structural specifications requested by the farm. We met these requirements by using programs such as Solidworks and Design Builder. After the farm approved our final design, we built the greenhouse according to these specifications.

Advisor: Ahmet Sabuncu

Sponsor: Lisa Burris, Turn Back Time Farm

Design

Harvesting Mechanical Energy

Laura Carlson, Theresa Cloutier, Allanah Kalka-Riffel,
Kishan Patel, Kevin Pawlak

With the increasing push for sustainability, more industries are looking for ways to incorporate renewable energy. With the amount of machinery being used around the world, researchers are beginning to investigate machine vibrations as a renewable energy source. This project aimed to create a working prototype that demonstrates the ability of piezoelectric materials to generate electricity from these vibrations. The final prototype design not only harvested electricity, but also successfully dampened excess vibrations to protect the machinery. The design included a square tile that housed the piezoelectric circuit, dampening subsystem, and supported the blender. Upon final testing, the prototype was able to charge a capacitor. With a dampening system, the prototype generated 8 millivolts.

Advisor: Brian Savilonis

Design

Small-Scale Vortex Induced Vibration Wind Energy Harvesters

Frank Ciliberto, Carly Neeld, Brooke Pierce, Ethan Shipulski

The goal of this project was to find innovative ways to harvest wind energy using phenomena known as vortex shedding and aeroelastic fluttering. We developed two vibrational small-scale wind energy harvesters, employing the use of a bluff body and an airfoil. We compared the theoretical natural and shedding frequencies to determine parameters for the spring constants in each system. Using an electromagnetic transducer, we harvested up to 1 milliwatt of power. We demonstrated the feasibility of our designs and explored the possibilities of scaling the system for use in different applications.

Advisor: Brian Savilonis

Design

Sustainable Building Materials

Peter Aliogo, Alexander Avakian, Talon Boie,
Chisom Okafor, Daniel Venkitachalam

Lack of affordable housing is a major global issue in the 21st century. This is especially prevalent in developing countries, where millions are living in unsuitable shelters and are earning less than U.S. $1-2 per day. In this project, we use our understanding of engineering and finance to provide a holistic solution for affordable and self-sufficient housing that can be applied anywhere in the world. Our building design integrates active and passive solar, wind power, and water filtration and collection in order to generate its own electrical power and maintain its own drinking water, respectively. The mechanical and thermal properties of the building materials are tested to meet structural standards. A multi-tier financial model is then used to develop a self-sufficient low-cost housing for families of different income levels.

Advisor: Winston Soboyejo

Design

Low-Profile Planar Home Speaker System

MacKenzie Hridel, Katherine Novak, Brent Reissman, Theodore Vangos, Katherine Williamson

The goal of this Major Qualifying Project was to further improve upon previous efforts to develop a low-profile planar home speaker system, with a focus on extending low frequencies. Our main objective was to reduce the size of the overall assembly using design for manufacturability approaches. This system is comprised of passive radiator bass boxes and resonant panels, driven by moving magnet transducers (MMT). The MMT was scaled down by half in each direction, leading to a complete redesign. The passive radiator was altered and refined to accommodate the new MMT. Improvements on the previous resonant panel include adding a second panel and having the two displace in opposite directions, creating a breathing motion. Utilizing modelling and simulation software along with test equipment, the team analyzed and iterated the design of each component. This process was repeated until the designs met performance requirements and produced adequately low frequencies.

Advisor: Joe Stabile

Sponsor: Bose Corporation

Design

A Biodegradable Alternative to the Single-Use Cup

Jessica Hanley, Ryan Herrmann, Tess Hudak, Rose Lewis, Peter Ross

One hundred billion single-use cups are sent to landfills annually in the United States. Their production, usage, and disposal cause deforestation, pollution, and human health problems. Attempts have been made to produce more environmentally friendly tableware, however, these options are frequently not economically or logistically viable. This project strived to develop a single-use cup that meets the market need while remaining biodegradable and sustainably sourced. A financial and market analysis demonstrates the cup's ability to enter the industry.

Advisors: Walter Towner (MG), Sarah Wodin-Schwartz

Automated Optical Inspection of MEMS Based Cochlear Implant Hydrophones

Sarah Bachli, Libertad Escobar, Angela MacLeod, Colette Ruden

The goal of the project was to design and integrate an efficient automated optical inspection procedure to characterize hydrophone sensor membranes for the fully implantable cochlear implant in development at the UniversitätsSpital Zurich. These membranes are a vital component of the sensor for registering sound. The goal was accomplished through the research, design, and prototyping of control systems and programs for image capture and processing. The finalized procedure is time-saving and optimized for optical inspection tests which were previously not feasible. This project lays the foundation for the fully automated optical inspection of multiple hydrophone membranes. This allows researchers to draw conclusions from data comparison to produce functional cochlear implants.

Advisor: Sarah Wodin-Schwartz

Sponsor: UniversitätsSpital Zurich & Cochlear, Ltd.

Manufacturing

3D Printing Using a PA12/NdFeB Filament

Miles Nallen, Kyle Opiekun, Tyler Rauch

The purpose of this project was to design, build, and modify a conventional 3D printer with the goal of printing magnetic parts. The ability to 3D print NdFeB magnets allows for greater design freedom as well as lower costs, since the NdFeB is mixed with PA 12 Nylon plastic. The first step in this process was designing and building the 3D printer. Once this was accomplished the filament was developed with a weight ratio percentage of 20% NdFeB to 80% PA 12 Nylon. Following the development of the filament, a solenoid was constructed. This solenoid was then placed on the nozzle of the 3D printer in order to align the magnetic particles during the printing process. Future work will focus on optimizing the nozzle and the applied magnetic fields to enhance the residual magnetic strengths and geometries.

Advisor: Joseph Stabile

Sponsor: Kalenian Foundation

Materials

Investigating the Properties of 3D-Printed Polymer-Metal Composites Containing Surface-Modified Stainless Steel Powder Reinforcement

Joseph Calnan, Andrea Claudio-Palacios, Jack Grubbs, Richard Smith

Polymer-metal composites (PMCs) have attracted interest in the transportation sector due to their promising mechanical properties, potential lightweight structural applications, and additional functionalities. However, PMCs also present challenges due to (1) complex processing and (2) insufficient adhesion between the metal particles and the polymer matrix. Fused deposition modeling (FDM) is an additive manufacturing method that could simplify the fabrication of PMCs, enabling their widespread use. Additionally, surface modification of the metal reinforcement could improve interfacial adhesion in PMCs. Thus, FDM of ABS-based PMCs using surface-modified steel powders was the focus of this study. Processing conditions and interfacial adhesion were systematically investigated using characterization techniques to evaluate the resulting mechanical properties of these novel materials.

Advisors: Germano Iannacchione (PH), Diana Lados

Materials

Buckled Battery Structures

Cesar Guerrero

Flexible energy-storage devices have attracted growing attention with the fast development of bendable electronic systems. However, it still remains a challenge to find reliable electrode materials with both high mechanical flexibility/toughness and excellent electrical and lithium-ion conductivity. This project describes the fabrication and characterization of stretchable and conductive polymer nanocomposites embedded with carbon nanotubes (CNTs) for application in flexible lithium-ion batteries. To exhibit even higher levels of strain rate a buckling method is performed. The systematic optimization of the buckled morphology is implemented by controllably stretching the poly dimethylsiloxane (PDMS) substrate, spin-coating the nanocomposites on the surface, and releasing PDMS to create consistent micro-buckles on the nanocomposite layer. It is demonstrated that the CNT-embedded Poly (vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) nanocomposites are capable of good electrochemical performance with mechanical flexibility, suggesting these nanocomposites could be outstanding anode candidates for use in flexible lithium-ion batteries.

Advisors: Jianyu Liang, Winston Soboyejo

Materials

Fire Helmet Redesign

William Bass, Thomas Chiudina, Max Marks

The goal of this project was to redesign the traditional fire helmet to fix certain problems that local firefighters experience. These problems include decreased mobility, weight, and deterioration. Although there are technologically superior helmet designs available, the Worcester Fire Department continues to use the traditional design because of a limited budget. The main problem this project addressed is the restricted mobility caused by the brim and the standard air tank. We worked closely with the Grove Street Station to clarify the main problems with their helmets and determine design specifications. The report defines this project, outlines design and testing methods, and considers the next steps in improving our design.

Advisor: Jianyu Liang

Materials

Controlling BiI3 Crystal Orientation Using Close-Space Sublimation for Solar Cell Application

James McRae, Emily Molstad, Risbel Rivas, Emma Ruano

Bismuth triiodide (BiI_3) has favorable photovoltaic properties for solar cells due to its ideal band gap of 1.8 eV. Previous research has been conducted on BiI_3 for photovoltaics through solution-processing that show the orientation of the crystals to be random. This random crystal orientation is thought to attribute to the low performance of the solar cells. However, BiI_3 thin-films can be fabricated using evaporation techniques as well, though little research has been done in the past and no literature exists on evaporated BiI_3 in functioning solar cells. Our group has developed a close-space sublimation (CSS) technique for consistently fabricating BiI_3 films. CSS allows for control over the vertical or horizontal orientation of the BiI_3 crystals. When evaporating, moderating the source-substrate temperature difference results in the variance of crystal orientation. A large processing temperature difference has been found to result in vertical crystals, and a small difference resulting in horizontal crystals.

Our group has fabricated functioning solar cells using CSS-fabricated, vertically oriented BiI_3 as the absorber layer. We hypothesized that vertically oriented BiI_3 will enable easier charge transport due to fewer grain boundaries, thus increasing efficiency. It can be seen in SEM images that the vertically oriented cells formed a more consistent film coverage allowing for the production of a voltage and current. The SEM images from horizontally oriented cells show grains that are either sporadic or in clusters, but do not fully provide coverage.

The experimentation focused on source temperature, time, and annealing conditions. Samples were characterized using SEM, optical imaging, and absorbance measurements while full cells underwent performance testing.

Advisor: Pratap Rao

Austempering AISI 5160 Steel

Jocelyn Abdallah, Abdullah Al-Shawk

This report discusses the relationship between the transformation from austinite to bainite and the material's hardness, ductility and yield strength. AISI 5160 steel samples were heated until they were entirely austinite and then subjected to the austempering process, submerged in 316°C austempering salt for 1, 2, 5, 30, or 90 minutes depending on the sample. Samples were also prepared using water quenching and annealing for comparison. The samples were then cut, ground, and polished using standard sample preparation methods for analysis using optical microscopy and x-ray diffraction. Separate samples in the form of tensile testing bars were prepared similarly. Vickers microhardness, Rockwell hardness, and tensile testing was performed. Analysis of the samples and tests showed an increase in bainite as the austempering time increased, the rate of formation for the bainite decreasing as more of the sample was converted.

Advisors: Richard Sisson, Mei Yang

Materials

Design Flow Electrolysis Cell

Kyle Arnold, Glenndon McCormick

With the electronics industry advancing rapidly, the demand for lithium-ion batteries is rising globally, creating a need for a reliable lithium recycling method. One such method is the electrochemical extraction of lithium from a source solution to a recovery solution using an ion exchange membrane and lithiated and de-lithiated $LiMn_2O_4$-coated electrodes. This method passes an electric current through the electrodes which are submerged in 0.1 mol/L LiCl and 0.05 mol/L KCl solutions for two hours, which is then repeated after the electrodes are swapped between the solutions. Using this method, we have investigated the effects of varying levels of de-lithiation, as well as the method's lithium extraction capability and applicability to a real battery solution of $LiNH_4OHSO_4Na$. From our testing, both the KCl and the battery solution were found to extract lithium from the source solution, confirming the effectiveness of this electrochemical method.

Advisor: Yan Wang

Materials

High Entropy Alloys

Arkady Gobernik, John Haddad, Connor Lemay

The purpose of this project was to assist in the modeling, casting, and testing of aluminum based high entropy alloys. The goal was to create a castable alloy having more tensile strength than traditional aluminum alloys, while retaining properties such as being light weight and cost effective. This was done by modeling and casting alloys with FCC structures initially composed of aluminum, zinc, and magnesium, and later composed of aluminum, zinc, magnesium, copper, and silicon. This was done by conducting tensile test and castability experiments of the composed alloys to compare to other present alloys.

Advisor: Yu Zhong

Sponsor: Metal Processing Institute

Robotics

NASA RMC 2019

Anh Dao, Luis Delatorre

Our project focused the WPI robot that participates in NASA's Robotic Mining Competition and improving upon the current design for the upcoming 2019 competition while adhering to the new rules. The previous iteration of the robot, Ibex, suffered from jamming issues and was unable to excavate the regolith simulant utilized in the competition, in addition to having exposed electronics without any dust proof casing and the lack of competent self-localization. To address these issues, our team focused on understanding the underlying causes of these problems to mitigate the effects. We found that the previous manufacturing of the digging scoops, selection of gearbox, and dated electronic hardware all contribute towards negatively impacting the robot's efficiency. We provided support to the scoops through chain guides and altering the scoop fastening design to resolve the jamming and digging ineffectiveness. In addition, autonomy is the second major focus for this year. To achieve this goal, we swapped out the entire previous complexed control system to a more integrated and unified hardware. Together with camera vision and sensors, our robot can operate autonomously and ready to compete in the 2019 Robotic Mining Competition.

Advisors: Michael Ciaraldi (CS), Kenneth Stafford

Robotics

PhleAid: Automated Phlebotomy Assistant

Gabriela Morales-Castillo, Angelina Nicolella, Carlos Pacheco, Armando Zubillaga,

The goal of this project is to minimize pre-analytical errors and simplify the phlebotomy process. PhleAid, the Automated Phlebotomy Assistant, implements a combination of three subsystems: a vial selection system, a vial handling and labeling system and a blood verification system. The vial selection system chooses the appropriate vial for each test through a graphical input and decision-making system that utilizes a microprocessor and database. The vial handling and labeling system minimizes user contact with the blood specimen by implementing our designed hardware, stepper motors and proximity sensors. Additionally, a barcode scanner is implemented to identify each blood vial. Finally, the blood verification system utilizes a series of photodiodes, LEDs and amplifiers to detect the level of blood inside the vial. This system ensures that the volume of blood obtained is sufficient for testing. Overall these subsystems work together to achieve our goal.

Advisor: Gregory Fischer

Robotics

Soft Matter Manipulation

Mingqi Shuai, Michelle Zhang

While the automation of planar sewing is a rather mature technology, the automation of sewing in three-dimensional space is still a challenging task to accomplish and is mostly done by human workers in factories. Our project researches into automating the sewing process by designing a system for soft matter manipulation. We proposed a design that utilizes a symmetric pin system that consists of a set of motorized top pins and passive bottom counter-parts. The system is able to form complex curves in both two-dimensional and three-dimensional space. Our project is subject to future iterations to integrate the system into new technologies used in factory processes.

Advisors: Zhi Li, Marko Popovic (PH)

Robotics

Sailbot

Sydney Fisher, Kellen Randall, Sierra Palmer

The goal of this MQP is to create an autonomous sailboat, known as Sailbot, that builds upon lessons learned from the previous Sailbot projects. We use the rules of the International Robotics Sailing Regatta (IRSR) to help guide us in creating the boat for the 2019 competition. The final products of this MQP are a more reliable boat, a better navigation system, and a user friendly guide on how to run the Sailbot.

Advisors: William Michalson (ECE), Kenneth Stafford

Robotics

Autonomous Scale Car Using Computer Vision and Neural Network

Mitchell Curbelo, Ryan Darnley, Ava Karet, Krishna Madhurkar, Dylan McKillip, Ethan Schutzman, Christian Scillitoe

This project explores the feasibility of creating an autonomous 1:10 scale car capable of racing against RC cars on any indoor track. Prior to conducting autonomous testing, a custom made scale car equipped with passive suspension was designed and manufactured. Comprised mainly of 3D printed parts, the car used rear-wheel drive with independent front and rear suspensions. Additionally, tachometers, strain gages, temperature sensors, and an inertial measurement unit were integrated to determine vehicle performance. The data from all sensors were displayed in real time on a webpage. For autonomous navigation, the car leveraged Artificial Neural Networks to produce optimal driving outputs. Taking grayscale pixel input from a single, front-facing camera, the car down-sampled and masked the input data to locate brown walls. Without relying on mapping or localization, the car collected high quantities of training data to navigate variable track conditions. Ultimately, the training produced a car that could perform partial laps under its own control.

Advisors: Kaveh Pahlavan (ECE), Pradeep Radhakrishnan

Robotics

Developing a Modular Control Moment Gyroscope for Planetary Rover Mobility

Aidan Brawley, Stephen Burke, Fang Han, Oliver Sanderson, Jeremy Wiles

A control moment gyroscope (CMG) is a torque actuator typically used for spacecraft attitude control, but other applications of CMGs are seldom seen in practice. The goals of this project were to design, manufacture, and analyze a modular CMG for use in any application. The developed prototype consisted of a turned brass flywheel suspended in a servo-powered, aluminum gimbal structure; it was able to produce a nominal output torque of up to 6 Nm. A microcontroller was used to simulate CMG dynamics, control the motors, and calculate performance metrics. Quantitative analyses were conducted for the behaviors of the motors, dynamic disturbances in the system, and stresses in the structure. To further validate the design, its output torque performance was evaluated against a theoretical CMG model developed in Simulink. Subsequently, to exemplify the prototype's modularity, its use on planetary rovers for rollover prevention and recovery was substantiated through computer simulations; rollover recovery was also physically demonstrated. These applications aimed to address NASA's Space Technology Grand Challenge of "All Access Mobility", which identifies the need for next-generation rovers to safely traverse any terrain type.

Advisor: Pradeep Radhakrishnan

Robotics

Development of a Modular Animatronic Head

Matthew Dick, Owen France, Richard Hosea, Kevin Le,
Rachel Lia, Patrick Meehan, Kyle Seymour

Innovation in the field of animatronics has been driven primarily by the entertainment industry designing highly specialized and expensive systems. To make animatronics more commonly used and low cost, multi-use and cost-effective animatronics must be developed. Through this project, a modular animatronic head has been developed that can be configured for various applications ranging from entertainment to medical training. The head uses linkage-based mechanisms, designed in 3D modeling software, prototyped using 3D printing, and driven by micro-servo motors. Motions of features of a human head, such as the eyes, eyebrows, and mouth have been replicated. Additionally, a silicone skin with connection nodes to interface with the linkages was cast from a mold of the head. These mechanisms have been designed to scale to different sizes and to accommodate variations in spacing of the human features that have been replicated. The structural integrity of the linkages were tested using finite element modeling. Motion capture data from a human was compared with the simulation and prototype to verify replicated movements. Different expressions have been programmed to replicate facial gestures. Details of design, prototyping, and analysis will be discussed in depth in the report.

Advisor: Pradeep Radhakrishnan

Thermofluids

Thermal Performance Modeling of Desert House in Neot Semadar, Israel

Sarah Boecker

This project aimed to provide guidance to its sponsor-the construction and housing manager at a small kibbutz community in the Negev Desert in Israel-on the factors of housing construction that influence thermal performance and therefore energy efficiency of the buildings within that region. This project examined the trends that should be present in houses specific to the region based on thermal mass, insulation, glazing, directional positioning, envelope design, and the relationship between convection and radiation within the house. These trends were compared to 1) actual temperature and humidity values collected by a Worcester Polytechnic Institute Interdisciplinary Qualifying Project team in two houses on-site and 2) data collected from single-change iterations of a baseline DesignBuilder model of one of these houses created on-site. The knowledge gained from this project and written up in an approachable format enables the sponsor to strive for informed building design and renovation in the future.

Advisors: Bland Addison (INGS), Isa Braun

Sponsor: Yoram Tencer, Head of Construction at Kibbutz Neot Semadar, Israel

Thermofluids

Low Ambient Air Source Heat Pumps Utilizing Cascade Cycles

Stephan Barthold, Brandon Cohen, Michelle Hull, Tyler Wilson

This project was in response to the loss of capacity, thus efficiency, in heat pumps as temperatures drop below 25 degrees F. The goal of this project was to determine if the addition of a cascade cycle to a commercial heat pump would increase the efficiency in low ambient temperatures. The testing acquired anemometer and thermocouple readings and simulated the effects of a cascade cycle on an R-410a Trane 5 ton Precedent Heat Pump unit utilizing a scroll compressor and normal operating conditions of 45/120/15 (saturated suction temperature/ saturated discharge temperature/degrees of superheat) at 3-phase nominal voltage 208-240V. Engineering Evaluation Software (EES) was utilized to simulate the heat pump model with and without the cascade cycle.

Advisors: Robert Daniello, Christopher Scarpino

Sponsor: Trane

Thermofluids

Phase Change Energy Storage Implementing Recycled Materials

Kieran Bradley, Malachi Nelson, Jillian Onishi,
Christopher Tillotson

This project involved the development and design of a hybrid thermal energy storage system to reduce financial and environmental costs of thermal energy. Energy storage is achieved in the form of latent heat, primarily using solar energy collected during peak hours. Phase change materials were chosen for their high energy density across small temperature increments, increasing efficiency and product lifetime. Utilization of waste and recycled products was a focus of this project affecting material choices resulting in the choice of P-116 paraffin wax as the phase change material. Computational thermal simulations were conducted to provide insight to help optimize the storage system design; based on this a prototype was experimentally tested with promising results. A dynamic system was designed with scaling possible for home or industrial scale systems.

Advisor: Selcuk Guceri

Thermofluids

Saving Energy and Cost During Peak Periods

Geraldine Benn, Christine Flores, Alison LaBarge

On the hottest days of summer, a typical household consumes 20-30% more electricity than average reflecting an increase in air conditioner usage. To address this need, utility companies must invest in expensive and inefficient “peaker plants” to meet high demand which results in increased prices for consumers during peak periods that can last up to eight hours. Utility companies encourage customers to shift power usage to off-peak hours to reduce strain on the grid. However, customers must balance their desire for comfort with cost. Our goal was to design a heat exchanger that stores “coolness” to assist with cooling loads during peak periods. Using numerical values representative of the Worcester, MA area, the proposed heat exchanger can store a maximum of 18 kWh of thermal energy and produce air at 16.2°C through a home’s existing heating, ventilation and air conditioning system.

Advisor: Selcuk Guceri

Thermofluids

Consideration of an Exterior Water Spray System for the Protection of Residential Structures from the Impingement of Firebrands During a Wildfire Event

Shannon Alvarez, Mitchell Pastizzo

Wildfires place residential homes at risk in the Wildland Urban Interface (WUI). This project utilized a Performance-Based Design approach to develop and evaluate an exterior water spray system to improve the survivability of a residential structure from a firebrand exposure during a wildfire. A fire scenario was developed to quantify the wildfire threat and study the impact of firebrands on residential structures. Firebrand transport and accumulation were modeled using Fire Dynamics Simulator (FDS). A water spray system was developed to meet specific goals for the scenario and consists of a tank and pump to supply the system.

Advisors: Milosh Puchovsky (FPE), Albert Simeoni (FPE)

Thermofluids

Development of an Off Grid Solar Powered Milk Refrigeration Solution

Brandon Abad, Michael Curtis, Kyle Havey, Peter Nash,
Joseph Stapleton, Luke Xu

The goal of this project is to design and build a milk refrigerator that could work off-the-grid. The refrigerator was designed to have the capacity to maintain freshness of 25 liters of milk, or half of the daily milk yield. Rural farmers are forced to either discard their "evening milk," or milk produced by cows in the evening, or sell it at a fraction of the market price of milk due to deteriorating quality. With the assistance of the refrigerator in this study, rural farmers in sub-Saharan will be able to sell their "evening milk" the next morning at full value without worry of it spoiling overnight. The refrigerator was manufactured using a steel frame, polystyrene insulation, copper tubing, and a repurposed refrigeration system from a mini-fridge. The refrigerator functions by cooling and freezing water during the day using solar energy, and using the ice to cool the milk stored in the copper tubes in the evening, similar to a heat exchanger. While the milk is cooling, a pump is circulating the milk in the copper tubes to ensure even cooling and a greater heat flux.

Advisor: Ahmet Sabuncu

Sponsor: Hunt Institute

Thermofluids

Atmospheric Water Generation

Christopher Bolsinger, Spencer Ralphs

Affordable access to potable water is a global issue, as approximately 844 million people around the world lack access to clean water. Atmospheric water generation can address this issue by generating potable water from the water vapor present in air. One technology to be utilized for atmospheric water generation is the vapor compression cycle (VCC), which generates water from ambient air by cycling a refrigerant to create a cold surface on which water vapor will condense. The parameters for condensation are dependent upon environmental constraints, including temperature and humidity of the ambient air. The scope of this project is to design and build a prototype VCC capable of delivering 500cc of liquid water from ambient air per hour. To do this, the system was first simulated using the relevant thermodynamic and heat transfer phenomena in the VCC to determine the design parameters. The simulation results dictated the purchasing of various components and assembling of hardware to achieve the aforementioned goal of 500cc/hour as a proof of concept for further future research into adaptation for large scale ecological applications, such as hydroponic greenhouses. With successful water generation in low humidity ambient Worcester conditions, the VCC will be extremely efficacious in supplying potable water to a community when integrated in a constantly humid hydroponic greenhouse.

Advisor: Jamal Yagoobi

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