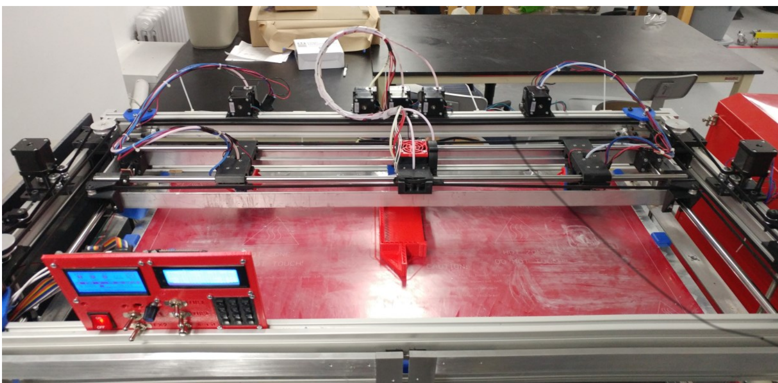
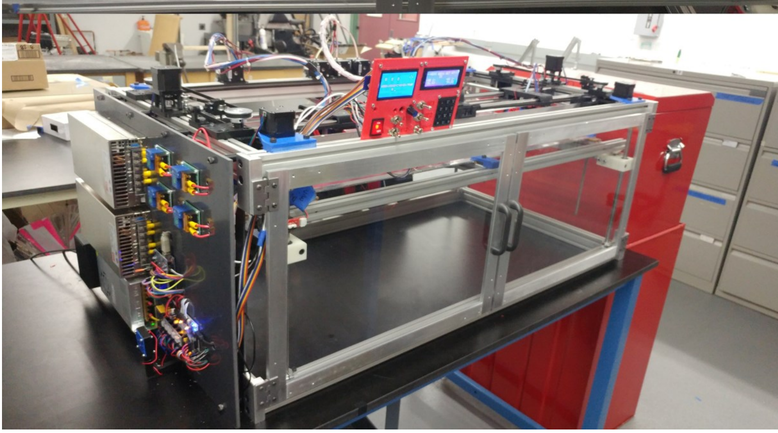
Worcester Polytechnic Institute

Mechanical Engineering Department





Project Presentation Day
April 20, 2017

Schedule for Project Presentation Day
Mechanical Engineering Department
April 20, 2017

8:00 AM	Judges Assemble	Higgins Labs 102
8:00 - 8:30 AM	Breakfast	
	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	Lunch	
	Judges	Higgins Labs 102
	Students	Alden Hall
1:00 - 1:15 PM	Winners Announced	Alden Hall

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Biomechanical

Design of a Transfer Device for an Eight Year Old Student

Lindsey Andrews, Jonathan Rheaume, Yingzhe Zhao

The goal of this project was to facilitate the transfer of an eight-year-old student with cerebral palsy from her wheelchair to an existing standing assist device by designing an attachment for the standing device. The transfer to and from the standing device used to require two aides, which was demanding in the school environment. A four-bar slider mechanism, driven by a linear actuator, was designed to rotate a frame from a position over her wheelchair to the standing device. The client is suspended from the crossbar of this frame in a quick to don and stable harness. Additionally, the transfer mechanism has a small footprint outside of the initial device, which was important for use in a public school. The mechanism facilitates the client's transfer by a single aide more quickly and with less physical exertion. Initial tests by the client were performed and feedback was returned.

Advisors: Holly Ault, Allen Hoffman

Sponsor: Sally Goodhile, PT at Worcester Public Schools

Biomechanical

Synthesizing an Artificial Hand for Tasks Requiring Fine Motor Control

Caitlin Grow

A C6 spinal cord injury can result in severe lack of fine motor control in both hands. Fine motor control is essential for overall independence and improved quality of life. Through this project, a planar artificial hand was synthesized based on the requirements of a person with C6 spinal cord injury. Among the various requirements were that the device was easy to use and portable in addition to being purely mechanical. Extensive research on existing products were carried out and a final design was generated. The design incorporated a body powered voluntary opening technique as well as a fixed and a pivoting prehensor. A prototype was manufactured and tested to verify conformance to simulation. The prototype was tested on the client as well.

Advisor: Pradeep Radhakrishnan

Biomechanical

Equine Lung Function Testing

Lucy Garvey, Lubna Hassan, Kyla Nichols, Allison Paquin

Up to 80 percent of horses experience respiratory disorders in their lifetime. Current diagnostic methods are invasive, expensive, and stressful. Cummings School of Veterinary Medicine at Tufts University is the only facility in New England with a non-invasive equine respiratory testing device. However, this device poses a risk to operators because it is not well attached, heavy, and protrudes 12 inches from the horse's muzzle, causing it to disconnect and harm the operator if the horse moves suddenly. Seeking improvements, our team designed and calibrated a safer, less expensive, noninvasive device to measure equine lung function to improve testing availability and market potential. This small, lightweight device uses a thermistor-based sensor to measure airflow at low flow speeds. A unique LabVIEW program displays both inspiratory and expiratory flow in a way that is easy for the veterinarian to use for diagnoses and for explaining the results to the client.

Advisors: Robert Daniello, Marsha Rolle (BE)

Sponsor: Dr. Melissa Mazan at Cummings School of Veterinary Medicine at Tufts University

Biomechanical

Designing a Biomimetic Prosthetic Flipper for a Kemps Ridley Sea Turtle

Frederick Burgwardt, Paul DePlacido, Andrew Dunne, Christopher Ryan, William Pope, Aryelle Teixeira

Lola, a Kemp's Ridley sea turtle located at the Key West Aquarium, has an amputated right pectoral flipper that causes her to swim inefficiently. A previous WPI team developed a first generation prosthesis to imitate Lola's healthy flipper. Our team focused our efforts on creating a lightweight, durable attachment that minimized application time and aligned properly to the residual limb. Our group developed a variety of designs to address these goals, communicated these ideas to the aquarium personnel, and sent prototypes to be tested on Lola. A final design was created in order to maximize the efficiency of the device, while maintaining the biomechanics of the original flipper design. The final prosthesis attaches securely and easily and provides Lola with the ability to swim evenly and effectively. This work created a foundation that can be applied to other amputee turtles in order to improve their quality of life.

Advisor: Brian Savilonis

Biomechanical

Improved Backpacking Load Carriage System

Delaney Cassidy, Emma Healey, Kimberlee Kocienski,
Ben Pulver

This project developed a novel load carriage system with an active suspension and pivoting hip belt for recreational backpackers. The design was validated with a controlled study of 5 male subjects. Quantitative and qualitative results were gathered to compare the experimental backpack to a commercial backpack. The results showed that the design did not meet the performance specifications for reducing oscillating load, ground reaction forces, and compression and shear at the lumbosacral joint. However, the design did meet the specification for reducing fatigue, showing a 6% VO2max ± 4% decrease. The design also induced the desired amount of forward lean, between 12 and 30 degrees. Overall, this project was a proof of concept of a small form factor oscillating load backpack that, with improvements to the suspension, could achieve even greater functionality.

Advisor: Brian Savilonis

Biomechanical

Finite Element Analysis and 3-D Printing of the Shoulder Joint and Glenohumeral Labral Tears

Kenneth Swanson

The objective of this MQP was to investigate the stresses experienced during a variety of loading conditions for shoulders that had experienced labral tears. Labral tears affect as many as 4.1 million people annually, and predominately occur on the superior portion, with the severity of the tear limiting a person's motion greatly. These analyses were developed using SolidWorks and ANSYS to model the shoulder and labral tear, with the model itself being printable as a physical reference for shoulder motion. Using general shoulder movements including abduction, adduction, and flexion, the force loads necessary to create tears were found. These loads far exceed day-to-day activities, but propagation of pre-existing tears will occur based on this model for strenuous motion.

Advisor: Satya Shivkumar

Biomechanical

Designing a Passive Knee Brace for Sit-to-Stand Assistance

Ethan Paul

Individuals experiencing diminished leg strength often encounter difficulty performing the transition from a sitting to a standing position. A healthy adult will complete an average of sixty transitions per day, making it one of the most physically demanding tasks performed in day-to-day life. The septuagenarian population of the United States increased by 7% in fifty years, and as such the number of persons lacking the ability to successfully complete the Sit to Stand Transition (STST) has also been increasing. To address this growing need, this project designed and fabricated a portable, wearable, passive mechanism that can be mounted on an individual's leg in to provide an assistive knee extension moment during the STST. The final design was a spring driven ratchet and cam system that stores the potential energy expended during sitting for usage during standing in order to deliver between 10 and 15 Newtons of lifting force. This mechanism serves as the prototype and proof-of-concept for an eventual market-ready product.

Advisor: Karen Troy (BE)

Design of a Customizable Assistive Utensil Grip

Kyle Fitzgerald, Adam Huber, Winton Parker

Assistive devices are commonly used throughout the world to help people with disabilities complete everyday activities. However, the market for these devices is limited to products that do not allow the user to adapt the device to best suit their needs. The objective of this project is to design an assistive utensil grip device to help individuals with limited grip strength and range of motion in the completion of daily tasks, while providing an aspect of customization not seen with currently available products. Three final designs were produced each with similar functional characteristics but employing different hand positioning when holding the device. The main advantage of the developed devices is the capability to adjust the orientation angles of the utensils for individual use. The range of utensils applicable for use with the device includes forks, spoons, knives, pens, and toothbrushes, but could be expanded with additional design efforts. Professionals in the field of rehabilitation analyzed and reviewed the three devices, and the feedback received from these professionals confirmed the functional effectiveness of the designs.

Advisors: Holly Ault, Allen Hoffman

Design

Design and Analysis of Cognitive Focus Devices

Brianna Fogal, Connor McGrath, Carolina Ramos,
Ashley Stanley, Daniel Sturman

The objectives of this project were to create a cognitive focus device, a business plan, and discuss whether fidgets can relieve oneself of the world's anxieties. The results were our product, the Fidget Egg, its commercialization, and a discussion about how some people center themselves through the use of sacred or secularized objects. The conclusions are: the Fidget Egg empowers consumers to direct their focus, there is no ideal fidget, and there may be a correlation with fidgets and industrialization.

Advisors: Torbjorn Bergstrom, Bland Addison (HU),
Walter Towner (MG), Helen Vassallo (MG)

Design

Designing and Building a Ski Binding Tester

Jesse Kablik

The goal of this Major Qualifying Project (MQP) was to design and build a ski binding tester that could be built at other locations. The tester was designed to meet the standards described in the American Society for Testing and Materials (ASTM) F504 document. Furthermore, the project aimed to add additional measurements for ski binding performance by analyzing the relationship between linear boot displacement in a ski binding and the moment about the z axis described in ASTM F504. The methods used in this project included the use of the program LabVIEW for data validation purposes, lever arm length ratios for displacement measurements, and two distinct pulley systems that produced forces capable of achieving the ASTM standards. The conclusion drawn from this project was that this ski binding tester, with a few modifications, could be built to produce repeatable test results.

Advisor: Christopher Brown

Multi-Mode Load-Limiting and Absorptive Ski Binding

Jacob Billington, Jonathan Comden, Sean Regan, Thomas Roberti

Using Axiomatic Design a new binding was designed to protect both the tibia from bending, twist and plateau fractures, and the knee from ACL injuries. It resists inadvertent release (IR), transmits control loads, and accommodates ski flex. IR is controlled by providing independent adjustability for the work to release. There is independently adjustable stiffness in the control and absorption phases of load transmission as well. The absorption phase allows for recoverable displacement, during which work is done on the binding rather than the leg. The toe and heel pieces of the binding are located in front of the toe and behind the heel, leaving space under the boot for vertical displacement at both toe and heel for addressing ACL BIAD injuries and compression fractures. Both toe and heel can displace laterally to provide dual mode lateral protection, avoiding combined valgus and inward rotation loading, which endangers the ACL. When the displacement reaches some adjustable limit, the toe and heel pieces will open simultaneously disconnecting the boot and the ski.

Advisor: Christopher Brown

Design

Extendable Pedal Car

Matthew Farrell, Alexa Stevens, Zachary Styer

Children grow extremely quickly, and parents are constantly replacing clothes, shoes, and toys to accommodate the size changes. To limit the need to replace toy vehicles, the goal of this project is to design and build a children's toy pedal car that extends with them as they grow between the ages of 5 and 7. This growing pedal car is the only toy automobile on the market in which the whole car extends for the selected age range, making the car useful for several years and comfortable for the growing child. The final design uses a telescoping frame to extend the distance from the seat to the pedals and an adjustable steering wheel to create a 10-inch extension to accommodate the average growth of children in this age range. The vehicle is recommended for a child up to 70 lbs. and tested to a safety weight of 210 lbs.

Advisor: Eben Cobb

Design

Quick Return Mechanism

Ellyn Webber, Zach Belohoubek

In order to further promote a deeper understanding of the design of mechanisms, we created a Quick Return Mechanism model that demonstrates how changing design parameters can alter the motion and time ratio of the device. Data from accelerometers on the mechanism were gathered and compared to the theoretical results from a mathematical model of the linkage. With this apparatus, a professor can easily demonstrate how a quick return mechanism functions on a theoretical and practical level to further students' comprehension of the kinematics of the mechanism.

Advisor: Eben Cobb

Design

Tabletop Demonstration Device

Jarrod Peloquin, Charles Bleakney

The goal of this MQP was to design a tabletop demonstration device to be used to aid students in understanding combined bending and torsional stresses. The device is a cantilever beam capable of being twisted measured amplitudes of strain with longevity of the device. We included the addition of strain gauges on the critical section of the main shaft of the beam to allow theoretical values of stress to be compared to measured values of stress.

Advisor: Eben Cobb

Design

Trash Lifter

Erin Bracken, Ian Converse, Michael Duclos

A full trash bag can be a difficult load to lift and drop into a dumpster, especially for the elderly. The goal of this project was to design a device that can safely and reliably assist the user in lifting a trash bag up and into a dumpster, such as those typically used by residents of an apartment building. This design is compatible with dumpsters up to five feet in height and can lift trash bags up to 50 lbs. in weight. The selected design consists of a four-bar mechanism in series with a driver dyad used to transmit power from the power source. The mechanism can be powered by either a hand crank or a 0.25 horsepower motor attached to the driver dyad.

Advisor: Eben Cobb

Design

Tree Stand Redesign

Huda Gad, Evan Pilaar

Nature photography is an ever-evolving field with a demand for innovative and creative shooting angles and locations. The team has identified a need for a device to help nature photographers climb trees and stay there for long periods of time to capture pictures of the fauna and flora around tree canopies. Several design concepts were considered before the team decided on a hang-on tree stand redesign. The new design emphasizes safety, portability and having a large angle of rotation, allowing photographers to access more vantage points than classic tree stands. Changing the design of the seat and integrating a swivel plate mechanism to the stand achieved the larger angle of rotation. A prototype was designed and built, weighing less than 25 lb. and supporting up to 350 lb.

Advisor: Eben Cobb

Design

Developing the Ice Device

Anthony DiBasio, Zoe Eggleston, Alexander Grammenos

In the United States, roughly 3,500 fatal drowning incidents are reported each year. A portion of which consist of cold water instances where the ice thickness of a frozen body of water is insufficient to support the weight of the individual, causing the ice underneath them to break. The proposed design is an autonomous thermistor chain which can be used to relay temperature data of a body of water such as lakes or ponds. The device utilizes thermistors to measure the electric resistivity of water/ice at various depths to quantify the ice thickness of a body of water. Thus eliminating the need for an individual walk out onto a potentially unsafe lake or pond to obtain a physical measurement. After designing and manufacturing a thermistor chain prototype, the team created a testing apparatus to simulate the freezing process of a body of freshwater such as a lake or pond. The data collected provides a representation of the accuracy of the device and serves as proof of concept.

Advisor: Robert Daniello

Design

Micro-Hydro Intake & Greenhouse Design

Aaron McGinnis, M. Paige Myatt, Nathan Peterson

The purpose of this project was twofold: a) to mitigate intake congestion of a micro-hydro power system at the Kearoa Marae in Horohoro, New Zealand, and b) to develop a basic feasibility assessment focusing on resource requirements for a commercial scale hydroponic greenhouse that would utilize electricity generated by the hydroelectric unit. To address the congestion of the micro-hydro intake, our team designed, constructed, and installed a self-cleaning floating boom across the inlet of the system to deter floating debris from entering the inlet, as well as a mesh screen to catch any submerged debris, reducing maintenance time and allowing the system to produce electricity to its fullest potential. Modeling the hydroponic greenhouse resulted in estimated heating, water, and electricity requirements that were used to develop recommendations to our sponsor, Te Runanga o Ngāti Kea Ngāti Tuara.

Advisors: Robert Daniello, Steve Kmiotek (CHE)

Sponsor: Te Runanga o Ngāti Kea Ngāti Tuara of Horohoro, New Zealand

Design

Design of a Hand Orthosis

Connor Kurtz, John Mulready, Steven Murphy, Tyler Tao

Persons with reduced hand strength and dexterity have difficulty completing activities of daily living. The project goal was to create an affordable hand orthosis for persons with reduced grip strength suitable for home use. The orthosis is wrist-activated and enables the user to form the cylindrical power grip and pincer precision grip. As the wrist flexes, pre-tensioned cables cause rigid finger channels to rotate and pull the fingers towards a fist. The device was manufactured mainly of plastic to keep weight (220g) and cost ($130) low. It provides a 13N grip force at a 45° wrist angle and the user can hold objects ranging in diameter from 7.5 to 45mm for the pincer grip and 30 to 80mm for the power grip. Testing indicates that the orthosis can assist users in performing daily tasks.

Advisor: Allen Hoffman

Design

Optical Chopsticks

Isaac Coelho, Matthew Haley

Light can apply mechanical forces to different objects due to its ability to carry momentum in addition to energy. This optical force can't be felt by humans because it is too small, but when shining a laser onto a single biological cell, you can hold it and move it to a different location without physically touching it. In this MQP project, we create an optical trap using laser emitted from the tips of optical fibers. These so-called "optical chopsticks" are composed of two parallel fibers with their tips polished to a 20° angle. The motivation of our MQP was the long time and poor repeatability of the existing polishing method to make these fiber tips. Our goal was to optimize the polishing method for better efficiency and repeatability, while not compromising the quality of fabricated fiber tips. We developed, fabricated, and tested three different designs of the fiber holder used in the polishing process. These designs allow reduction of the polished surface areas and a better control of the polishing depth of the fiber tips. Our designs result in a significant reduction of the polishing time by about 90% (from 8 hours to 40 minutes) and better control of the fiber tip shape. The fibers polished will then be evaluated by optical trapping of microparticles.

Advisor: Yuxiang Liu

Optical Conveyor Belt

Brandon Bozeat, Jonathan Stump

Fiber optics are widely used in optical telecommunications, including internet signals, to transmit information. Through special fabrication methods, the same optical fibers can be used for microscale biological applications, such as sensing and manipulating cells. These methods include heat-and-draw processes that reduce the diameter of the fiber to approximately 1 micrometer, resulting in a tapered profile. Particle manipulation is possible through light-matter interaction that occurs outside the physical boundary of the fibers throughout the tapered section. Common flame-based tapering processes are poorly repeatable and susceptible to instabilities, which cause losses of power transmission and diminish the taper's ability to manipulate particles.

Our goal was to develop an improved fabrication process to produce tapered fibers that have low losses in water and therefore have reliable particle trapping capabilities. We designed and built an electrical microfurnace that produced tapered fibers with up to 96% optical transmission in air, compared to ~80% transmission with the flame fabrication. In water, these fibers lost no more than an additional 33% of optical power, compared with ~80% loss with the flame method. With this significantly improved optical transmission, an optical conveyor belt has been experimentally demonstrated in water, with microscale particles trapped and propelled along the fiber taper.

Advisor: Yuxiang Liu

Design

Autonomous Aircraft Retrofit

Karl Sundberg

The purpose of this project was to address the feasibility of retrofitting a four passenger private aircraft into an autonomous cargo transportation vehicle. A custom mechanical control mechanism prototype was developed that would replace a human pilot. The prototype developed addressed the three main controls on aircraft; roll, pitch and lift. Using knowledge of the selected aircraft configuration, the mechanical design each component was designed, analyzed to meet FAA guidelines and industry standards, and then constructed to demonstrate operation.

Advisor: Fred Looft (ECE)

Design

Summer Kite Power 2

Andrew Bauer, Christopher Beauchemin, Alexander Draper, Obadiah Munene, Jonathan Van Blarcum, Hanqing Zhao

This project continued to optimize the design of the WPI Rotary Kite Powered Water Pump. This system is intended to provide cheap and reliable access to clean drinking water for developing nations. The main results of the project include producing a desired flow rate of about 600 L/hour, implementing a kite pump frame that lowered the center of gravity and reduced height below seven feet, producing an improved kite control box with remote control capabilities, implementing a rotary spring for kite retraction, and demonstrating intended control of the kite.

Advisor: David Olinger

Design

3-D Printing Thermal Expansion

Connor Barrett, Joseph Presing

The goal of this project was to better understand the residual stresses imparted upon 3D printed polymer parts and then to be able to predict irreversible thermal strain from annealing. Residual stresses in 3D printed pieces are, in part, controlled by raster angle and layer thickness, the two print parameters examined in this project. Utilizing first principles, we were able to fit equations of plane and shear stress to our experimental data and derive equations representing the magnitude and direction of irreversible thermal strain and shear strain. These equations were used to create an algorithm that takes desired final dimensions and outputs the necessary print parameters. This project added a new dimension to the additive manufacturing field by allowing for the creation of 3D printed one-way shape memory polymers. While the strength of pieces was not maximized, the project created a multi-functionality that previously did not exist.

Advisors: Amy Peterson (CHE), Anthony D'Amico (CHE)

Design

Design and Development of a Myoelectric Transradial Prosthesis

Cameron Currie, Cameron Downey, David McDonald,
A. Rae Nistler, Gregory Port, Joseph Sabatino, Steven Souto

The loss of a limb is a life-changing event and reality for 441,000 transradial amputees in the United States. Limb loss can have substantial physical, social, psychological, and economic consequences. A prototype prosthesis was created that has sophisticated hand functionality, an adjustable and comfortable socket, and a lightweight yet durable design utilizing 3D printing, all available at a reasonable price point. The prosthesis integrated force sensors, servo motors, and a myoelectric means of control so the user may perform activities of daily living. The overall outcome was a prosthesis that met its design requirements, offering increased usability, functionality, and availability.

Advisors: David Planchard, Tiffiny Butler (BE),
Sergey Makarov (EE), Craig Putnam (CS)

Design

Design and Optimization of a SAE Baja Chassis

Heather Selmer, Sabbrin Shweiki, Paige Tencati

The purpose of the Society of Automotive Engineers (SAE) Baja Major Qualifying Project (MQP) was to analyze the pre-existing BSAE vehicles to determine flaws and design a new chassis that improved upon the previous designs. This MQP identified particular problems with the size of the engine compartment, the overall suspension alignment and attachment points, as well as the visibly crooked nature of the vehicle. After consideration of possible solutions, the MQP created various preliminary designs utilizing the Baja SAE Rules as a guide for design decisions. Basic Finite Element Analysis (FEA) was conducted on the preliminary designs to determine which performed best in a head-on collision. Stress and deflection analyses in multiple scenarios were conducted on a design similar to the final design and changes were made accordingly until the frame could withstand the many rigors that a vehicle would endure during a Baja SAE competition. When designing the suspension, the MQP determined that a double A-arm would be suitable in the front and a trailing A-arm would be best in the rear. Each was designed using specific constraints. A quote to manufacture and weld the frame was requested from VR3 and all documentation needed was created so that the manufacturing process could be completed during the upcoming summer. Sound engineering design and analysis allowed this MQP to produce a chassis that will give an exceptional performance in future competitions.

Advisors: David Planchard, John Hall

Design

Design of a Personal Aerial Vehicle

Matthew Lepine

The purpose of this project was to research, design, and analyze a personal aerial vehicle. One focus of this objective was modeling and structurally analyzing the frame, which had to be lightweight, yet strong enough to withstand the stresses of the application. This was accomplished while also identifying other compatible components to complete the design. In pursuit of this goal, similar technologies were examined, allowing for a unique, yet practical, interpretation of this new technology. A tenth-scale prototype was designed and fabricated to assist in determining the electrical components necessary and to act as a functioning example of how a full-scale vehicle might operate. Finally, recommendations on future action were outlined to allow for further development of the technology.

Advisors: David Planchard, John Hall

Design

Optimization and Design of an FSAE Frame and Suspension

David Powers, Johnathan Ross, Constantine Scarperdas, Christian Storbel

The purpose of this MQP was to design and manufacture a new frame and suspension for use in the 2018 FSAE competition. Through analysis of the car entered in the 2016 competition, research, feedback from the previous designers, and critiques from the competition judges, optimized designs were developed. Improvements were made to the weight, ergonomics, impact strength, and reliability. Components were designed to incorporate the engine and other components from the previous car. Through the use of FEA the frame and suspension were tested to ensure the performance and safety of the final designs. The car's design also took into account the 2018 FSAE rules to ensure the car would be able to enter the competition easily and satisfy the judges requirements.

Advisors: David Planchard, John Hall, Kevin Sweeney (MG)

Design

Developing Automated Design and Analysis Tools

Corey Alicchio, Callum Taylor, Justin Vitiello

Design automation is complex and work is carried out in several stages. Staged development aids in recasting the results into virtual labs that can be used to improve understanding of design and analysis topics. In this project, during the first stage, a tool was developed to generate SolidWorks assemblies from design graphs of gear trains consisting of gear and shaft information. The tool was developed using SolidWorks API. In the second stage, automated creation of bond graphs from SolidWorks assemblies was carried out. The built-in feature recognition in SolidWorks is used to identify the geometric relationships between different components in the assembly and using grammar rules, a system graph is generated. This system graph is integrated into the automated bond graph generation tool from MQP 2015-16. The final stage involved development of grammar rules and logic to automatically extract state equations from bond graphs. The tools resulting from these activities are used in ME 4320 and ME/RBE 4322 courses at WPI.

Advisor: Pradeep Radhakrishnan

Design

Developing Methods and Graph Representations for Automated Design of Gear Trains

Penelope Belliard, Ruizhe Chen, Yingjie Lu

Design is an iterative process and automation can generate different solutions as well as save time when compared to designing manually. But automation requires identification of all the necessary steps and equations so that the designs can be correctly generated. This project focused on identifying the requirements that can be built into a software tool to automatically design gear trains. In the project's first stage, various kinematic- and stress-based gear and shaft design equations were sourced from different handbooks. Using these equations, designs for gear trains for three test problems were manually generated. In the second stage, the iterative design process was developed into a flow chart for implementation in the proposed software tool. The final stage involved developing graph representations for different types of gears and gear trains, as well as creating basic grammar rules to add gears and shafts based on input conditions.

Advisors: Pradeep Radhakrishnan, David Brown (CS)

Design

Terahertz Testing Fixture

Andrew Belz, Michael Cournoyer, Anthony Lawinger

Nanowires are currently being developed for use in next-generation solar cells. In order to produce and improve these solar cells, improved nanowire synthesis methods and non-contact measurement techniques are needed. The goal of this project was to design, build, and test a fixture for measuring both axial and radial conductivity of nanowires by terahertz spectroscopy. In order to measure conductivity along both directions, an adjustable rotating fixture for holding nanowire samples was designed and manufactured. The samples prepared for testing consisted of aligned and unaligned zinc oxide nanowires grown on both quartz and silicon substrates.

Advisors: Pratap Rao, Lyubov Titova (PH)

Towards the Optimization of a Fin-Based Hydropower Generator

Casey Broslawski, Frank DeGiacomo, Keaton Goddard, Christopher Parisi

This report outlines an improved means to design, manufacture, and test the fin-based hydropower generators prototyped by previous WPI MQP teams. The current MQP team introduced CFD and FEA into the design process, allowing them to study alternate fin designs and the feasibility of scaling the device. The team produced a new iteration of the cam-driven fin generator which was more reliable and amenable to testing than the original device. This new prototype was compatible with a Prony brake dynamometer, which meant the team was able to measure power and efficiency data. The team used the enhanced prototype and testing methodology to study the effect of fin stiffness, as controlled by fin thickness, on the device's overall performance. The team found that thinner, more flexible fins outperformed thicker, more rigid fins. The device's peak power and efficiency were 3 Watts and 4.5%, respectively. Scaling and further optimization of the device's design and manufacturing will further improve fin-based hydropower generators.

Advisor: Brian Savilonis

Design

The Synthesis and Design of a Small Speaker System

Shawna McGaffigan, Ryan Smolenski

Large speaker systems can produce high-quality sound in a large frequency range. Because bass requires a sufficient acoustic volume, currently available small speaker systems struggle to provide adequate low frequency content in a small enclosure. Recently, speaker systems are incorporating multiple passive radiators to increase low frequency capabilities. However, this takes up space in current designs and adds to package weight. The goal of this project was to create a small speaker system with two passive radiators but in a more efficient implementation. One of the passive radiators would use the speaker as the mass for the passive radiator, saving space. Package volume is compressed by locating the rear passive radiator adjacent to the front passive radiator, resulting in an ultra-thin package. The rear passive radiator is also lightly loaded, but force-balanced through area matching to the front passive radiator. An analysis of the design and its efficiency; along with 3D fabrication details and operational performance are discussed in this report.

Advisor: Joseph Stabile

Design

Design and Build an Innovative 3-D Printer

Alex Beaudoin, Nicholas Borowski, Robert Boulanger,
Paul Danielson, Jessica DiPersio, William Gorman,
Cameron Hastings, Daniel Pfaff, Michael Wray

3-D printing is rapidly becoming a vital manufacturing tool with applications for both professionals and hobbyists. Most consumer 3-D printers are limited by their print area and printing capabilities. The goal of this project was to design and construct a large-scale 3-D printer capable of printing in multiple colors and materials or multiple copies simultaneously. The resulting printer has a print area of 3.7 square feet; can accommodate one, two, or three print heads; and can print multi-colored prototypes without the need to change filament. The final design allows for an open view of the mechanical systems within the printer as well as open access to the electrical systems for use as an example of how 3-D Printers work.

Advisor: John Sullivan

Design

Engineering Experimentation Module Designs

Peter Ofsthun, Elizabeth Thompson

This project designed and prototyped a self-contained modularized alternative to the engineering experimentation course (ME3901) at WPI. The focus of the project was to develop a course based on an inexpensive laboratory kit for students that addresses the goals of engineering experimentation. The kit contains an Arduino based microcontroller, a collection of sensors and required electrical components. A module framework was developed with a unified structure that can be used as a template for additional instruction modules. Each module focuses on one topic: temperature, distance, motion, etc. These focused modules introduce the sensors appropriate for measurement/control of the topic. The modules illuminate how the sensors are configured for microcontroller I/O with full example circuit designs and associated code to accomplish the introductory exercises. The goal for each module is to include sufficient information to teach the students about the sensors while requiring them to perform more detailed tasks on their own to demonstrate knowledge. A final capstone module was designed as an open-ended assignment that incorporates several of the previous focused modules to achieve the capstone objective.

Advisor: John Sullivan

Design

Fetching Interactive Dog Occupier (FIDO)

Joseph Alvarado, Bianca Espinoza, Johnly Lin,
Doon Nordemann, Tiana Vasquez,

Dogs are great companions but they require a lot of attention and exercise. Many households are a two-salary household, which leaves the dog alone for many hours. Usually the dog is left with nothing to do but wait for their owners to get home. The Fetching Interactive Dog Occupier, or FIDO, team has designed a prototype to entertain and exercise dogs that are left home alone. FIDO plays fetch with the dog without the help of the owner. The dog can drop the tennis ball in the hopper system and the machine will shoot it out. The dog can continually play fetch with FIDO while its owners are at work. FIDO was designed with different settings for either indoor and/or outdoor use. Safeguards exist to prevent tossing a ball if the dog or child is in close proximity of the discharge tube. The prototype has been successfully field tested.

Advisor: John Sullivan

Design

Revamping ME3901 for Modular Distribution

Jeffrey Brathwaite

The goals of this project is to develop a supplementary package of various sensors, motors, and instructions that can give the same educational value of an experimentation course of WPI to one that might be online. To get this package together, I reviewed the materials currently covered in the experimentation course and selected several components to focus on. I assembled inexpensive equipment that not only satisfy the low cost condition but can collect and organize experimental data from each module. With the added instructions, students and non students alike might learn how to use a microcontroller to measure and/or control the various components commonly used for engineering experimentation.

Advisor: John Sullivan

Manufacturing

Analysis of Edge Curvature and Roughness in Slicing

Jake Porrazzo, Michael Sheahan, Scott Spear

The objective of this project is to investigate the strength of the correlations between the finish along an edge to the edge geometry and performance when slicing through a given material. We used a state of the art microscope to measure machined aluminum edges at fine scales. We used geometric multiscale analysis to characterize the edge and determine the relevant scales of measurement. We redesigned a testing device from a previous MQP to apply measurable forces when slicing through material. We used a dynamometer to measure the forces simultaneously. Using the microscope to analyze the edges before and after slicing, as well as the material after slicing, it was determined that various polished edge finishes resulted in differences in slicing performance.

Advisor: Christopher Brown

Materials

Development of an Experimental Optimization Method in Laser-Assisted Cold Spray

Sean Hathaway, Mikhail Khibkin, Matthew Nicholson

Current experimental optimization methods take extended periods of time and do not have a systematic way to get closer to the optimum. As a result, the team set out to generate a new, systematic approach to experimental optimization that costs time and cost. First, a theoretical goodness equation was used to predict the influential trends of parameters in the Laser-Assisted Cold Spray (LACS) process on three material properties. This was also used to select the algorithm used, Mine Blast Algorithm. The equation and algorithm was then modified for the experimental process which included a fourth variable. The team was able to achieve a goodness of 0.66 after only 5 iterations of the estimated 25 iterations necessary to achieve optimization (30 samples).

Advisor: Diran Apelian

Materials

Design of Small-Scale Furnace for Fire Resistance Testing of Building Construction Materials

Joseph Igoe Xander Ing Kevin Lynch, Dylan Martel, Lynn Renner, Tara Sharp, Austin Smith, Steve Thulin

Fire resistance testing is a critical tool that contributes to meeting the fire and life safety objectives prescribed by model building codes. For many types of building construction, these prescriptive codes employ structural fire engineering to promote the strategic placement of fire rated walls, partitions, and floor or roof assemblies. The ratings of these assemblies are determined by fire resistant test procedures, including ASTM E119, *Fire Tests of Building Construction and Materials*. Specific ratings are measured by an assembly's time to failure under a standardized fire exposure. Full-scale E119 furnace testing is expensive and not well suited to assembly optimization. The goal of this project was to build a small-scale furnace apparatus capable of performing economical fire resistance tests. Analyses supporting the design, manufacture and operation of a small-scale furnace test apparatus were conducted to establish correspondence between the small-scale furnace and the full-scale E119 furnace.

Advisor: Nicholas Dembsey (FPE)

Materials

Crack Detection Using Wavelets

Theofilos Gatsos

This paper develops an algorithm for the detection of cracks on bridge structures, based on the Wavelet Transform (WT). A review of the state of the art techniques for crack detection of beams and bridges is made, and numerical parametric studies for Finite Element Modeling and WT characteristics, such as wavelet type and noise effects, are performed. The results from these attempts are used for the development of a robust approach to detecting damage in bridge structures, introducing the concept of multiple-support-bridge crack detection. Both direct use of mode shapes and of moving load approaches to detection are made, commenting on the advantages and drawbacks of each. An overall assessment of the state of the art of WT damage detection is given in the concluding paragraphs.

Advisor: Zhikun Hou

Materials

Transport Properties Measurements in Aluminum Alloys

Gyneth Campbell, Scott Davison, Adam Gatehouse,
Daniel Mortarelli

The goals of this project were to build an apparatus for the automated measurement of thermal and electrical conductivities of metals, while developing an integrated methodology to further relate these physical properties to the materials' characteristic microstructures. Aluminum systems were selected for the study, which included both wrought (6061, 7075, 2024) and cast (A356, 319, A390) alloys. The microstructures of the materials were altered via chemistry and thermal modification (heat treatment) in order to systematically study the effects of grain size, secondary dendrite arm spacing (SDAS), and morphology of secondary phases (eutectic Si particles). A DC method was employed for the thermal and electrical (4-wire) conductivity measurements. The microstructures of the alloys were quantitatively characterized using an optical microscope with image analysis. Micro-hardness evaluations of the aluminum matrix before and after heat treatment were also performed. Novel relationships between the alloys conductivities and their characteristic microstructural features were uniquely established.

Advisors: Diana Lados, Germano Iannacchione (PH)

Materials

Assessing Carbon Footprint

Richard Coffin, Matthew Puksta, Muhammad Siddiq,
Antonio Tachiaos

This project was focused on the automotive recycling industry in Massachusetts. The study was sponsored by the Automotive Recyclers of Massachusetts (ARM). The goals of this study were to understand how much material is recovered, reused, and recycled and how these activities impact the state's carbon footprint. The report includes the understanding of how environmental hazards, such as waste oil, are processed. The primary method of data collection comprised of site visits for collecting information on number of cars processed, the type and volume of parts recovered and the amount of hazardous materials that are safely processed. The difference in carbon footprint between processing recycled materials and using primary raw materials have been analyzed. A survey of the members of ARM was conducted. The primary method of data analysis is through the use of 'Sustainable Minds' - a software program used to calculate the carbon footprint of the process involved. The study has determined that for this specific industry, the carbon footprint is significantly negative, however it is recommended that this study be furthered to include processes, such as shredding, smelting and casting.

Advisor: Brajendra Mishra

Materials

Fabrication and Properties of Novel Polymer-Metal Composites Using 3-D Printing

Daniel Braconnier, Kristin Markuson, Mila Maynard

This project investigated the novel fabrication and properties of polymer-metal composites (PMCs) using 3D printing (fused deposition modeling–FDM). Mechanical and physical properties of acrylonitrile butadiene styrene (ABS)–stainless steel PMCs (with 5,10,15, and 23 wt% stainless steel powder additions) were generated and compared with those of the base ABS. Tensile testing, dynamic mechanical analysis, differential scanning calorimetry, optical microscopy, and scanning electron microscopy were employed to characterize all materials/conditions. A new methodology to fabricate the composites was first developed. The resulting materials were then extruded into PMC filaments, which were further used to print tensile specimens. Controlling printing parameters, deposition layout and orientation were systematically investigated in order to optimize the process (minimize porosity and enhance homogeneity and interlayer bonding) and improve materials' properties. The results demonstrate feasibility of using 3D printing to create PMCs with increased functionality (magnetic and conductive properties), while preserving or enhancing their mechanical properties.

Advisors: Amy Peterson (CHE), Diana Lados,
Germano Iannacchione (PH)

Materials Engineering

Flexible Solar Cell

Francis LaRovere, Michael McMahon, Edward Peglow

Solar energy can be made more widely accessible by creating versatile solar cells that can be implemented in novel areas. Making solar cells mechanically flexible greatly increases their versatility. Current materials being used for flexible solar cells are unstable, expensive, inefficient, or toxic. The goal of our project was to synthesize flexible absorber, conductive and blocking layers out of earth-abundant, non-toxic materials to achieve solar cells that are both flexible and efficient. We chose antimony sulfide, copper(I) thiocyanate and titanium dioxide for these respective layers on the basis of efficiency, mechanical flexibility, cost, stability and safety. We explored low-temperature synthesis methods to realize this flexible design on a plastic substrate, and evaluated the design by observing the microstructural changes that occurred due to bending.

Advisors: Pratap Rao, Cagdas Onal

Robotics

Assistive Intelligence for Transradial Amputees

Sienna Mayer, Gabrielle O'Dell, Yesugey Sipka

Over 500,000 people in the United States are missing part or all of their lower arm, with more than 28 million more at risk for amputation. Unfortunately, current upper-limb prosthetic devices offer limited functionality and are prohibitively expensive, often ranging from $10,000 to $73,000. Users have been dissatisfied with the current products, with 70% of amputees stating the prosthetic hands limit activities of daily living, and 60% feel the hands limit the amount of work they are able to accomplish. Existing technologies require the user to exert significant cognitive burden to accomplish simple everyday tasks. Users have to visually close the loop while interacting with objects, which can severely inhibit functional utility and convenience. To address these challenges, we created a smart below-the-elbow prosthesis called Dexter that uses sensors and cameras to "feel" its environment and act intelligently. The project involves the design, fabrication, and testing of Dexter as an inexpensive, intuitive, and intelligent alternative to existing prosthetic hands. Dexter can adjust its position, orientation and grip based on visual and force feedback to detect objects, determine appropriate grasps, move objects without crushing, dropping, or spilling the contents, and perform functions like opening doors, without the need for extensive user input. We call this new paradigm "assistive intelligence." As the first intelligent anthropomorphic hand available for everyday use and advanced research applications alike, we ultimately expect that this device will bring about a paradigm shift in prosthetic design and engineering.

Advisors: Cagdas Onal, Kristen Billiar (BE),
William Michaelson (EE)

Robotics

Humanoid Stereoscopic Vision System

Tyler Chaulk, Rodrigo Rivas, Ann Votta, Jacob Wennersten

In 2014, a group of Worcester Polytechnic Institute students completed a major qualifying project (MQP) on the design of a mechanical stereoscopic vision system, named WPI Motor Eyes Mechanism. In this subsequent MQP, the original Motor Eyes system was evaluated, and the sources of error were identified through static analysis and dynamic testing. These problem areas were redesigned to create an improved Humanoid Stereoscopic Vision System that better adheres to the original design constraints. Once completed, work focused on implementing image processing technology. Cameras were installed to add facial detection functionality and further increase the capabilities of the system. The final result is a robotic platform that is able to visually locate and track a moving human face.

Advisors: Cagdas Onal, Holly Ault

Robotics

Accurate Prosthetic Hand

Casey Kracinovich, Mervyn Larrier, Dylan Renshaw,
Elina Saint-Elme

The purpose of this project, Accurate Prosthetic Hand, is to explore a method by which to improve the dexterity of artificial hands by closely mimicking the biomechanics of a human hand. The biomechanics of each human finger was analyzed to determine the kinematics and finger trajectories that the experimental hand should be able to mimic. In addition to the kinematics and finger trajectories, the biomechanics analysis was used to determine what materials were needed to simulate tendons and musculature of the human hand. The mechanical system of the experimental hand is actuated using several stepper motors controlled by electroencephalogram (EEG) signals and electromyograph (EMG) signals. The majority of the experimental hand's motions are controlled using EEG, with three distinct thoughts executing three distinct grips: pinch, hook, and point. EMG signals are used for finer motor control, such as controlling the strength of each grip pattern. The completion of this project resulted in a prosthetic hand capable of nine degrees of freedom as well as the creation of a control system that relies on sensory input from the mind and body; all while preserving the important biomechanical data that allows the human hand its unique dexterity.

Advisor: Marko Popovic (PH)

Robotics

Robodog

Yunda Li, Michael Pickett

Legged robots allow for travel over the variable terrain commonly found on Earth, which is more difficult for traditional wheeled systems. The MIT Leg Lab made great progress with both bipedal and quadruped robots in the 90s. Currently, advances have been made with legged robots through companies like Boston Dynamics. These robots provided the inspiration for Robodog. Legged robots pose a variety of challenges from mechanical design to control, and as a result, WPI has not produced many successful legged robots. For our project, we designed a quadrupedal robot to accomplish a basic walking gait. Robodog was designed and manufactured from the ground-up, and is the first step toward cheaper quadrupeds. This was accomplished using servo motors and a parallel elastic system to decrease motor load and increase efficiency. After extensive experimentation our quadruped is capable of successfully walking over rough terrain and up a small incline.

Advisors: Marko Popovic (PH), Pradeep Radhakrishnan

Robotics

Robotic Mining Platform

Dom Bozzuto, Rene Jacques, Aaron Jaeger, Brian Peterson, Yu-sen Wu

In-situ resource utilization, or the use of the resources available in a foreign environment, is crucial to the success of manned missions to Mars; however, it is a severely underdeveloped technology. This project explores the development of a rover capable of operating in a simulated Martian environment. The rover is capable of mining large amounts of simulated ice chunks from below the surface, driving its payload to a collection station, and unloading all of the collected material. This project is partially inspired by NASA's Robotic Mining Competition which served to establish a set of guidelines around which the robot was constructed.

Advisors: Kenneth Stafford, Michael Ciaraldi (CS)

Thermofluids

Modular Geothermal Heat Pumps

Veronica Delaney, Zachary Ericson, Keirstan Field

The goal of this MQP was to design a modular geothermal heat pump system. Existing geothermal heat pumps require specialized equipment for installation, and it is not feasible to conduct maintenance on the ground portion of the system once it is installed. Modularizing this technology would decrease installation cost and increase system life expectancy. The modularity of the system would allow additional modules to be installed as the heating load of the building changes. We created an analytical model of the thermodynamic heat cycle that occurs within a geothermal heat pump using desired heat output rate as a requirement of the system. Our model produces a recommended tube length for given heat output rate and is highly customizable to meet design requirements of a variety of situations.

Advisors: Robert Daniello, Christopher Scarpino

Thermofluids

Materials Fire and Thermal Properties - Low E Windows

Perry Ascani, Garrett Curran, Sai Sett Paing, Madelyn Werth

The use of Low-Emissivity windows has increased over the past 20 years to account for over 80% of residential windows currently in use. In specific cases these windows have caused vinyl siding deformation, or melting, on neighboring houses due to the focusing of sun energy from curved window surfaces. To better understand this problem, our goal was to create a tool to predict the possibility of siding damage in a given house and neighboring house set up in any location in the United States. Important factors include the prediction of sun angles and intensity, model of the sun intensity focusing from the window surface, application of a transient temperature analysis of a multilayered surface, and analysis of the damage due to time exposed to increased temperatures. From the use of this tool, we were able to identify the key factors that lead to the deformation of siding.

Advisor: Nicholas Dembsey (FPE)

Thermofluids

Vortex Tube Cooling System

Devin Duarte, Kimberly Rosa, Daniel Ruiz-Cadalso

All of the technology we rely on, from smartphones to laptops, is powered by semiconductor chips that continue to innovate in the miniaturization of their features. Smaller features lead to smaller tolerances in manufacturing, meaning that uniform and rapidly adaptable cooling is increasingly indispensable in photolithography processes. This project evaluated the use of a vortex tube for heat management of critical components of ASML's photolithography machines used in semiconductor manufacturing. This technology is not traditionally used in this setting, but is more adaptable and efficient than current solutions and provides an opportunity for innovation in this vital industry. Thorough analytical, computational, and experimental methods were developed to quantitatively study the feasibility of using the vortex tube in this application. Experiments were conducted in an environment designed and fabricated by the team to simulate specific chip manufacturing processes. Our results indicate that the vortex tube can be a viable alternative to current cooling systems.

Advisor: Cosme Furlong

Sponsor: ASML

Thermofluids

Design and Construction of an Advanced Solvent Recycling System (Acetone Distiller)

Travis Simoneau

Large amounts of Acetone and other similar volatile solvents are used in a wide ranging of industrial applications. In most cases, such liquids are commonly used for cleaning purposes and become contaminated with other chemicals, oil, water and small solid material. These solvents are discarded at substantial expense to the producers. In this project, a small scale recycling system is designed with the objective of achieving acceptable level of purity for reuse in a cleaning operation. The system is envisioned as a compact, totally self-contained, and mobile in a way. It can be relocated easily depending on the need. The system requires only electric power connection which can be supplied from any 120Volt, 20 Amp source. Instrumentation for unsupervised operation and safety is part of the design process.

Advisors: Selçuk Güçeri, Stephen Kmiotek

Thermofluids

Synthesis of an Air Manifold for an Adaptive Suspension System

Jake Nieto, Jorge Santana

The goal of this project is to synthesize an air manifold that regulates flow throughout an existing airbag suspension system for an automobile. The team estimated the requirements using fluid flow principles based on the requirements from the consumer. Different sensors and arrangements were investigated to ensure that the manifold can handle the requisite pressure requirements at each of the four wheels. A prototype was developed and tested to verify the performance and theoretical estimations.

Advisors: Pradeep Radhakrishnan, Robert Daniello

Thermofluids

Harvesting Hydrokinetic River Current Power

Megan Belval, Hallie Kenyon, Robert LaFlamme, Sarah Putnam

An original water energy harvesting mechanism was designed, manufactured, and tested to determine the feasibility of hydropower as a source of renewable energy. The device consists of a neoprene fin that moves in a sinusoidal motion, allowing fish to travel past it. This fin connects to a crankshaft that turns a generator. The device is optimal in low water current speeds, such as rivers or drainage pipes. Five fins of varied thicknesses were tested in water flow speeds between 0.5 m/s and 1.5 m/s using a torque watch and tachometer. The best fin tested was the 1/32" 50A durometer neoprene fin, which produced a power of 1.5 Watts and a 16% efficiency. This efficiency makes the prototype competitive with other water energy harvesting devices on the market and can be theoretically scaled up to have a larger efficiency.

Advisor: Brian Savilonis

Thermofluids

Vortex Induced Vibration Energy Harvesting Through Piezoelectric Transducers

Natalie Diltz, Julie Gagnon, Jacqueline O'Connor, Jessica Wedell

All of the technology we rely on, from smartphones to laptops, is powered by semiconductor chips that continue to innovate in the miniaturization of their features. Smaller features lead to smaller tolerances in manufacturing, meaning that uniform and rapidly adaptable cooling is increasingly indispensable in photolithography processes. This project evaluated the use of a vortex tube for heat management of critical components of ASML's photolithography machines used in semiconductor manufacturing. This technology is not traditionally used in this setting, but is more adaptable and efficient than current solutions and provides an opportunity for innovation in this vital industry. Thorough analytical, computational, and experimental methods were developed to quantitatively study the feasibility of using the vortex tube in this application. Experiments were conducted in an environment designed and fabricated by the team to simulate specific chip manufacturing processes. Our results indicate that the vortex tube can be a viable alternative to current cooling systems.

Advisor: Brian Savilonis

Thermofluids

Next Generation, Smart Fluid Storage Tank for Space and Terrestrial Applications

Jon Barruetabena, Connor McGuirk, Lily Ouellette

Technology which utilizes the electrohydrodynamic (EHD) phenomena is smart and self-driven. In 2020, NASA will be sending this satellite and space technology to the ISS for testing. Our project explores the application of EHD conduction pumping to mix fluids non-mechanically in the absence of gravity. Our first-of-its-kind, EHD embedded spherical tank design actively homogenizes the temperature within and avoids vaporization of the liquid. The EHD conduction pumping mechanism provides fluid circulation via the dissociation of electrolytes when subjected to an electric field. Our design is used for testing, which is conducted in WPI's state of the art multi-scale heat transfer laboratory. Through temperature and velocity measurements EHD mixing was quantified for our Major Qualifying Project. The testing proves that this technology is viable and paves the way for future advancements in the field.

Advisor: Jamal Yagoobi

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