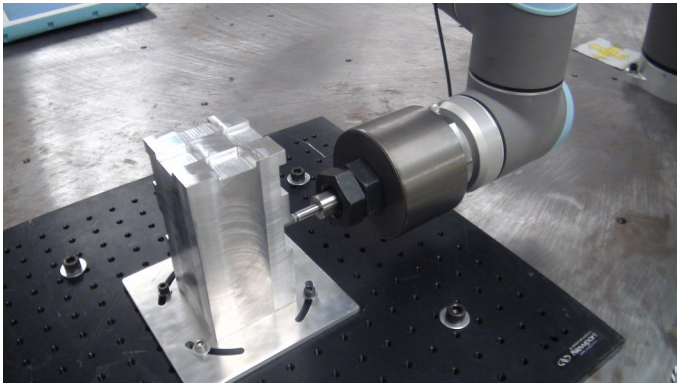
Worcester Polytechnic Institute

Mechanical Engineering Department



2014 Project Presentation Day April 24, 2014

Schedule for Project Presentation Day
Mechanical Engineering Department
April 24, 2014

8:00 AM	Judges assemble	Higgins Labs 102
8:00 AM to 8:30 AM	Refreshments Judges Students	 Higgins Labs 102 Alden Hall
8:15 AM to 8:30 AM	Judges Instructions	Higgins Labs 102
8:30 AM to 12:00 PM	Presentations	Alden Hall
12:00 PM to 1:00 PM	Lunch Judges Students	 Higgins Labs 102 Alden Hall
1:00 PM to 1:15 PM	Winners announced	Alden Hall

Table of Contents

Biomechanical

Alternative Knee Brace Design

Sarah Cook, Amanda Cormier, Zachary Tomkinson

The objective of this project is to reduce Anterior Crucial Ligament (ACL) injury during alpine skiing through the design of a novel bracing system to protect the ACL. ACL tears as a result of alpine skiing increased by 103% between 1972 and 2006, showing a significant need for an effective brace. The most common causes for ACL injuries during alpine skiing are Boot Induced Anterior Drawer (BIAD) and Valgus Collapse. Axiomatic Design, which includes two axioms, maintains independence and minimizes information, was used to generate and evaluate design alternatives and final design selection. Tolerances and material selections were determined based on the laxity of the ACL. Force analysis was used to finalize the computer model. Finite Element Analysis (FEA) was completed to evaluate how the device will perform under common loads seen by the ACL during alpine skiing.

Advisor: Christopher Brown

Biomechanical

Exomuscular Sleeve for Upper Limb Stroke Rehabilitation

Ritesh Adhikari, Michael Cross, Timothy Forrest, Hosung Im, Jason Klein, Anselm Mak, Julieth Ochoa

Traditional physical therapy for upper-limb post-stroke hemiparetic patients suffers from time and money complications, often fails to reach the maximum potential for recovery, and is unable to provide a complete, quantitative assessment of a patient's progress. Through the use of robotics, the team aimed to create a device which would not have these shortcomings and would provide a holistic physical therapy solution. The sleeve achieves exomuscular actuation through a system of Bowden cables linked to DC motors housed in a backpack and is able to flex and extend the fingers and elbow and control pronation and supination of the wrist. Through a sensor array located throughout, a feedback system is able to collect quantitative data on position and pressure, and control all degrees of freedom utilizing this data and several on-board processors.

Advisors: Edward Clancy (ECE), Greg Fischer, Cagdas Onal

Biomechanical

Design of a Protective Device for Head and Neck Injuries in Football

Tyler S. Hanna, Zachary K. Hennings, Michele L. Mensing, Evan J. Perry, Ralle A. Rookey

One of the leading sources of head and neck injuries in sports is football, accounting for 10.6% of injuries each year. Current helmets protect the skull during linear impacts, however, new research identifies rotational effects of impacts as major concussion contributors. The goal of the project was to reduce the likeliness of a concussion by limiting the rotational velocity and duration of acceleration of the head during high impact forces through design of football equipment. The team designed and manufactured a rotational shock absorber which transfers impact energy directed at the head to the body, causing the torso to rotate and reducing the acceleration and velocity experienced by the brain. The concept was first analyzed with ANSYS Fluent to verify proper response, and then tested in concussive-simulating situations. Linear and angular head acceleration, velocity, and displacement were compared for testing with and without the rotational shock absorber.

Advisors: Brian Savilonis, E. Tuzel (PHY)

Biomechanical

The Design of an Adjustable Ankle Support

Ximena M. Auger, Aleksandra R. LaRue, Nicole M. McDonough, Isabel H. Pagliaccio, Asher B. Plange

The objective of this project is to reduce the incidence of ankle inversion and eversion injuries by designing, prototyping, and testing a new brace that would provide three stages of ankle support and rehabilitation. There are many ankle braces in the market today; however, they are all targeted toward a specific stage during rehabilitation. Buying a new brace for each step of recovery has proven to be costly. Analysis, material selection, and computer aided design drawings were conducted as well as the development of a prototype brace and testing apparatus. Using a force plate and potentiometer to record data, human test subjects were used to test the new design against an unbraced ankle as well as a brace commonly found in the market. Statistical analysis was performed and the recorded reaction time as well as the center of pressure data supports our conclusion that the designed brace increases stability.

Advisor: Brian Savilonis

Biomechanical

Use of Magnesium Alloys in Tension Band Wiring of Olecranon Fractures

Joseph Gay, Louisa King, Adrienne Lysen

Fractures of the olecranon are common elbow injuries and represent about 10% of the upper extremity lesions. Surgical fixation of this fracture through tension band wiring involves inserting two 316L or Ti alloy pins and a tension band wire in a figure eight configuration. After the fracture is healed, the hardware is typically removed. The feasibility of using biodegradable AZ31 magnesium alloy for this application is examined. A 3D computer model of the elbow was developed from X-ray CT scans. The model was evaluated using finite element analysis. The ability of magnesium to withstand stresses needed to fix the olecranon properly was evaluated and compared with that of 316L. A 3D model of the elbow was used to verify the results from the finite element model. The data suggest that AZ31 has the potential to be a viable material that can be used in tension band wiring of olecranon fractures.

Advisor: Satya Shivkumar

Design

Designing Experiments for an Undergraduate Clean Energy Laboratory

Marshall B. Bernklow, Ian Corcoran

This project was designed with the focus of improving alternative energy education at WPI. Laboratory experiences for students need to incorporate both the knowledge that students need as well as a practical hands on experience with the subject matter, in this case thermoelectrics. Research was conducted to identify similar projects and experiments used in other academic and professional curriculums that would relate to the individual topics of alternative energy. From there a laboratory procedure was created that would not only be informative for students about the specific alternative energy topic, but could also be engaging so as to promote subject retention. This lab was broken into 2 parts, one focusing on the basics of thermoelectrics while the other focuses on understanding some of the more complicated concepts. The labs were reviewed and run through by the MQP group in order to stream-line the procedure and determine overall effectiveness.

Advisor: Isa Bar-on

Design

Renewable Energy Lab

Steven Cortesa, Adam Morin, Jack Tyson

As the topic of clean energy becomes ever more important to our society, WPI must develop courses on this topic to remain at the forefront of university education. There are currently no courses on clean energy at an undergraduate level at Worcester Polytechnic Institute. This project identified clean energy topics that could be investigated in a college laboratory setting and created laboratory procedures on topics deemed appropriate. The topics of energy density, photovoltaic energy, anaerobic digestion, and bioethanol production were identified as the most appropriate choices for a university laboratory setting, and a laboratory procedure for each of these topics is contained within this report.

Advisor: Isa Bar-on

Design

ACL Injury Reducing Ski Binding Plate

Nathan Braun

Injuries to the anterior cruciate ligament (ACL) are the most prevalent injury in the sport of alpine skiing. Prevention of ACL injuries is one of the biggest issues facing the alpine skiing industry today. Many skiers who experience an ACL injury will retire from the sport, and those who do return are more likely to experience the injury again. ACL injuries cost patients upwards of $250 million a year. Typical alpine ski bindings are good at preventing some injuries, but they do not target the mechanisms of ACL injuries. This project aims to solve the issue by adding a binding mounting plate between the binding and the ski targeting the most common mechanism of ACL injury, known as Phantom Foot, which is attributed to ACL strain due to inward Valgus rotation. Utilizing the axiomatic design process, the solution to preventing Phantom Foot was determined to be a pivot point about the toe, allowing dampened lateral displacement at the heel of the boot. This project analyzes several potential designs to absorb the injurious forces during the phantom foot scenario in an attempt to determine the most effective design.

Advisor: Christopher Brown

Design

Advanced Assessment of Ski Bindings

Kelsey Wall, Brendan Walsh

Using Nam Suh's Axiomatic Design method, this project focused on mitigating inadvertent ski binding releases during non-injurious situations. With the development of a torque-displacement system, the work required to release a ski boot from its binding can be calculated. Measuring this work-to-release will identify a bindings shock absorptive capabilities, and thus its susceptibility to inadvertent release. Initial procedures considered such a system's fundamental requirements and customer constraints in order simplify the device, and increase the likelihood for success. An electronic torque to release dynamometer was designed, manufactured, tested, and shown to yield accurate torque-to-release values. Several displacement sensors were explored and tested as viable options for binding test procedures, but were found to be non-viable. However, several inexpensive displacement alternatives were developed and recommendations for their possible inclusion in future work were also made.

Advisor: Christopher Brown

Design

Bamboo Bicycle

Michael Andres, Charles Brock, Dean Dellechiaie,
Joseph Giesecke, Malcolm Fano, Edward Lukowski,
Jeffrey Quinn, David Richardson

There is a need for cheap transportation in third world countries. Bicycles are a common mode of transportation, however are not affordable for widespread use. Bamboo bicycles are a cheap alternative, however current manufacturing processes are labor and time intensive. Our goal was to design a cost efficient process for manufacturing bamboo bicycles that can be assembled in less than one hour. Axiomatic Design was used to decompose the problem into functional requirements and design parameters. Our primary focus was to develop a more efficient method for creating the bike joints. The result was metal joints to produce easier manufacturability of the bike. The joints were created in SolidWorks. Our design was then run through a finite element analysis software.

Advisor: Christopher Brown

Design

Load Limiting Passive K3 Below-Knee Prosthetic

Sarah Basehore, Tyler Bouchard, John Foy, Jerrod Heiser, Alexander Verrelli, Chadwick Whitcher

In the US, there are approximately 1.7 million people living with limb loss and there are over 120,000 below-knee amputations performed annually. The disadvantages of the current prosthetics on the market stem from either a lack of performance or high cost. There is a growing need to provide an affordable lower limb prosthetic device that provides functionality for everyday activities. The objective of this project is to use axiomatic design processes to design and prototype a successful load-limiting below knee prosthetic ankle and foot. The success of the prototype will be determined by its ability to perform the mechanical requirements desired for a K3 prosthetic. A CAD model was first created in SolidWorks and then fabricated using CNC machining. To test its success, the prototype was tested on a human subject using force plates and analyzed using Netforce software for data acquisition and Bioanalysis software for gait, balance, and power.

Advisor: Christopher Brown

Design

Adjustable Mount Skate Blade

Andrew Childs

Figure skating requires precise blade/foot placement to maximize efficiency, which is made difficult when a person suffers from over pronation or supination. Only around 30% of people have normal foot placement, meaning the other 70% suffer from some degree of over pronation or supination (Leading Edge Physiotherapy), which has a significant effect on a person's ability to skate. To overcome this problem, skaters have been mounting and remounting their blades to the boot, experimenting with different angles until the optimal angle is achieved. While this solution addresses the problem, it is time consuming and skate boots are often ruined in the process.

The primary goal of this project is to develop a device which allows a figure skater to simply and easily adjust the angle of a skate blade to the optimal position without ruining the boot in the process. The project consisted of a design stage in which the individual components were developed, a rapid prototyping stage in which designs were physically examined before being refined, and a prototyping stage in which the final design was machined. The final design utilizes a worm gear to allow for an infinitely adjustable blade placement angle and set screws at the rear and clamps at the toe to secure the blade in position.

Advisor: Eben Cobb

Design

Canoe Lifting Device

John Mallers

The primary goal is to design an assistive device to aid the user and help transfer their canoe/ kayak from the ground to the roof of their vehicle. After selecting the original design, a four bar linkage, changes were made to suit the application and allow it to simplify the process of loading a canoe on to a car. Two identical six bar mechanisms are attached to either end of the canoe powered by a hand driven crank that helps the mechanism load the boat on top of the car.

Advisor: Eben Cobb

Design

Quick Return Mechanism

Sebastian Bellisario, Mengxi Han

The purpose of our project was to explore the characteristics of kinematic quick return devices, and characterize the major differences between quick return and other kinematic machines. These differences would allow us to develop a demonstration device which would be used to help future students understand how quick return machines function, and how to produce a specified motion with them. Our machine is a Whitworth quick return mechanism designed to run at low speed, to highlight the differences between front and back strokes. Additionally, the device allows for easy changing of the timing ratio.

Advisor: Eben Cobb

Design

Design of an Intermediate Scale Fire Testing Rig for Exterior Wall Assemblies

Christopher Ciampa, Ethan Forbes, Ditton Kawalya

Together with higher expectations for building performance such as energy efficiency, combustible materials are increasingly being added to exterior wall assemblies requiring them to pass the full scale fire test standard NFPA 285 (Multi-story building test). This testing procedure is expensive and time consuming to perform. The project aimed to design an intermediate scale fire testing rig for screening fire (and thermal) behavior of exterior facades. A light and easy to use intermediate scale rig would benefit many people in the construction industry. By reducing the size and cost of the assembly specimens in the screening test more effective and efficient assembly designs can be developed with confidence that these assemblies with pass the full scale NFPA 285 test.

Advisor: Nicholas Dembsey (FPE), Umberto Berardi (CEE)

Sponsor: Kreysler and Associates

Design

Development of Hand Control Interface for Manual Transmission Vehicles

Zachary Bornemann, John LaCamera, Leo Torrente

The goal of the MQP is to design and build a minimally invasive hand control interface that can be used by paraplegics or double leg amputees to control manual transmission automobiles. This control interface can also be used by individuals who describe themselves as car enthusiasts and enjoy driving manual transmission vehicles. The primary components of the control interface are mechanical linkages and a steel cable system to actuate the brake and clutch pedals of an automobile. The Guidosimplex 'Duck' Semi-Automatic Clutch and Alfred Bekker Manual Hand Clutch are some of the common products that offer control of the gas, brake, and clutch to the user. However these products are expensive, invasive, and do not enable full control of the car. The team conducted testing and research in several areas including the analysis of current assistive devices, calculating the dynamics of the mechanical linkages, brake system, and manufacturing a prototype control interface. Compared to earlier control interfaces, the team was able to design and build a mechanical control interface with reduced components and ease of installation.

Advisor: Mustapha Fofana

Design

Dangerous Inspection and Versatile Exploration Robot (DIVER)

Jillian Chalke, Christopher Conley, Gregory Hutchinson, Paul O'Brien, Victor Puksta,

The use of professional scuba diving teams is an industry practice for multiple commercial, research and military applications. Professional divers can be deployed into dangerous conditions where surface communication may be limited. In these situations, remotely operated vehicles (ROV's) can be implemented to improve communication and ensure personnel safety and mission success. The Dangerous Inspection and Versatile Exploration Robot (DIVER) is design to assist, track and monitor professional divers in commercial, military and research applications. The remotely operated DIVER vehicle is lightweight and versatile to allow rapid deployment and ease of communication amongst professional scuba diving teams. Using a combination of commercially available and custom made components, the DIVER team created a user friendly and highly mobile ROV platform. The team conducted background research on the state-of-the art of underwater robots, and determined specific applications and features necessary for the proposed DIVER vehicle. Mechanical engineers in the team designed the components of the DIVER vehicle for manufacturability, strength and compactness. The Robotics engineers integrated electrical and software components to allow for usability and functionality. Advanced real time tracking algorithms are developed. These algorithms allow autonomous operation while integration of a video game controller provides the user with a familiar platform for tele-operational driving. The DIVER vehicle is designed to be used on wide range of platforms. It provides the user with greater opportunities to modify components and payloads based on specific applications.

Advisor: Mustapha Fofana

Design

Development of ISO Compliant Repeatability Procedures for Evaluating Collaborative Robots

Joshua Baker, Timothy Kurisko, Haoran Li, David Poganski, James Worcester

The goal of this project is to provide the sponsor with a test fixture and procedures in order to characterize positioning repeatability and accuracy of collaborative robots as a function of payload and acceleration according to ISO 9283. Using the Universal Robot's model UR10 as a testing platform, the objective was accomplished by analyzing the current state of the art techniques for robot characterization; completing a vibrational analysis to select and implement suitable metrology equipment; designing, optimizing, and manufacturing a test fixture; developing a testing procedure and software; and applying the fixture and test procedures to characterize positioning repeatability. The outcomes prove the potential of the developed methods and equipment for expansion to additional projects of interest to the sponsor.

Advisors: Cosme Furlong, Diana Lados

Sponsor: Gillette

Design

Assistive Mobility Device for an Elementary School Student with Arthrogryposis

Nicholas Algiere, Alan Humphrey, Grant Raymond

An eight year old male in a Worcester public school has arthrogryposis, a condition which prevents him from using his arms and walking. He has access to several mobility devices; however, they are all unfit for use in a classroom setting. The student has learned to write and type using his feet and, as a result, he works at a specialized desk. The goal of this project was to design and manufacture a custom mobility device suited for the student's specific needs. A device was created that could easily navigate a classroom, while still providing a comfortable, ergonomic seat and a safe, stable platform that would allow him to work at his desk. The main features of the device include: a zero turning radius, lateral support, lockable wheels and adjustability to increase the effective life of the device. It is currently being tested in the school to evaluate the efficacy of the design.

Advisors: Allen Hoffman, Holly Ault

Design

Passive Assistive Pedaling Device

Caroline Allen, Audrey Blasius, Katelyn Puttre

Cycling for post-stroke rehabilitation usually occurs indoors on a stationary bicycle designed for a user with equal leg strength. Cycling training could be improved if it could occur outdoors and account for the weakness of the user's affected leg due to hemiparesis. This MQP develops a drivetrain for an adult tricycle to allow for rehabilitative and recreational use. The drivetrain was designed so that each crank rotates on a fixed axle at a speed relative to the size of the chainring. Each chainring is connected to separate sprockets on the rear axle with a gear ratio of 2:1. The drivetrain has the potential to be set up so that the patient can pedal with their affected leg on the smaller chainring for more repetition, or on the larger chainring for more strength training. Testing indicated that users can adapt to the irregular pedaling pattern and that the potential for adjustability would make the design suitable for post-stroke rehabilitation.

Advisors: Allen Hoffman, Holly Ault, Eben Cobb

Design

Powered Hand Orthosis (2)

Ian Crowe, Reed Hebert, Brittany Nichols

Most hand orthotics are rigid and hold the hand in a fixed position. The goal of this project was to design and manufacture a powered hand orthosis to allow persons with dexterity and strength impairments to regain hand function necessary for independence by providing cylindrical and key grips. Based upon research into existing devices, three preliminary designs were developed with full analyses and were ranked according to our design specifications to select the final design. The prototype device uses cables to pull the fingers closed, a geared mechanism to raise and lower the thumb and a linear actuator to close it. Three degrees of freedom are controlled by two rocker switches for closure and a potentiometer for thumb rotation. These three switches are contained within a hand held enclosure that is worn on a belt. The device was found to function as expected and provided the motion necessary for the desired grips.

Advisors: Allen Hoffman, Holly Ault

Design

Motor Eyes: Mechanical Platform for a Binocular Vision System

William Kiely, Wut Yee Oo, Olive Rappoli, Brian Strobel, Raphael Walcott

Stereoscopic vision systems, which introduce depth to an image by overlaying two separate perspectives of the image, require high computational power to perform image processing. The required processing power can be reduced by synchronizing eye movements to direct their respective lines of sight to the same point, aligning the images. To reduce synchronization error, eye movements can be coupled mechanically. To investigate this potential, the project team developed, analyzed, constructed, and tested a mechanical platform for a binocular robotic vision system. The design uses linear motion and slider linkages to couple the eye movements, with each degree of freedom being actuated by a stepper motor. The motor positions are recorded by encoders and controlled by PID program implemented in Arduino Uno. A prototype mechanical platform was constructed, capable of pointing two eye components at an individual point of interest through mechanically coupled pan, coupled tilt and coupled vergence movements.

Advisors: Cagdas Onal, Holly Ault

Design

A Scalable Liquid Current Power Generator

Ryan Bussett, Christopher Chaggaris, Michael O'Regan, Andrew Turgeon

The goal of the project was to design and manufacture a scalable, liquid current power generator capable of harnessing energy contained in ocean currents for electrical applications. The project team utilized a coreless, direct drive, three phase axial-flux alternator driven by a pair three-blade, diametrical flow Gorlov turbines. To develop the design, the group used several softwares. DS SolidWorks was used to model design iterations for the machine. For the alternator design and analysis, a LoadLine analysis was done in MATLAB to allow easy modification during development. The group manufactured the machine using several resources, including two Makerbot Replicator 2 3D printers, several Haas CNC machines available in Washburn Shops, and multiple traditional open machines. To test the machine, the group first analyzed the machine's power output at various speeds in a lab environment. Then, the device was ultimately tested using the WPI Recreation Center Crew Tanks in order to effectively simulate a current flow scenario.

Advisors: David Planchard, Alexander Emanuel (ECE)

Design

Design and Optimization of a Formula SAE Vehicle

Matthew Chareth, Eduardo Fernandez, Eric Gehrken, William Grebe, Camden Mallette, Vincent McMahon, Tyler Moser, Justin Paprota

The purpose of the Formula SAE Competition is to provide students the opportunity to design and build a prototype race car for an amateur autocross racer and then demonstrate its performance in a competition setting. The project team built upon a car that was originally intended for use in the 2012 FSAE Collegiate Competition. The team performed component evaluation and reviewed past project team's reports to determine what systems needed to be completed to make the car both operational and competitive. The areas that were addressed include the rear suspension, exhaust, tuning the continuously variable transmission (CVT), and the body. All of the systems being addressed have been designed and validated. These subsystems were then manufactured and integrated with the existing car.

Advisors: David Planchard, William Michalson (ECE)

Design

Society of Automotive Engineers Baja MQP

Bertan Atamer, Julian Enjamio, Stephen Oliveria,
Travis VanDale, Jeffery Wong

Worcester Polytechnic Institute (WPI) was developing a racecar for the Society of Automotive Engineers Baja (BSAE) competition. Due to changes in the competition's rules, specifically a change in the roll cage's minimum metal tube wall thickness, the WPI racecar became ineligible to compete. This Major Qualifying Project (MQP) tested the BSAE racecar, identified deficiencies inherent to the frame's design, then developed and fabricated a completely updated and legal BSAE racecar frame eligible for future competitions. Additionally, the team undertook an engineering outreach initiative by collaborating with Assabet Valley Regional Technical High School. In exchange for fabricating the frame, the team educated the Assabet Valley shop students about the engineering principals behind the new racecar's design. Finally, the team validated the new frame by utilizing finite element analysis software, preforming a design review in accordance with SAE guidelines, and concluding with a comparison of the final deliverable to the previous BSAE frame design.

Advisor: David Planchard

Design

Optimization of Caterpillar's 980H Rear Protection System

Marissa Goerke, Matthew Franklin

Two WPI students collaborated with four Shanghai University students under Caterpillar Inc. sponsorship to redesign and optimize a rear protection system for custom ordered 980H Wheel Loaders for use in strenuous workplace environments. A final design, meeting all Caterpillar Inc.'s specifications, was created by an iterative design process focusing on innovative and resourceful design ideas, meeting ISO standards, strength, accessibility, safety, aesthetics and simplicity.

Advisor: Yiming (Kevin) Rong

Sponsor: Caterpillar Inc.

Design

Tyco Nurse Call Pull Station Redesign

Mariela Qirici, Mark McCabe

This Major Qualifying Project (MQP) involves the mechanical redesign of a nurse call pull station produced by Tyco International Ltd. The nurse call pull station was redesigned in order to improve functionality, to reduce variability in activation forces, to eliminate the ultrasonic welding assembly process, and to reduce of manufacturing cost.

Advisor: Yiming (Kevin) Rong

Sponsor: Tyco International Ltd.

Design

Enclosed Vertical Axis Wind Turbine

Paige Archinal, Jefferson Lee, Ryan Pollin, Mark Shooter

Vertical Axis Wind Turbines (VAWTs) are a renewable energy technology suitable for low-speed and multidirectional wind environments. Their smaller scale and low cut-in speed make this technology well-adapted for end-user adoption, but performance may still be improved. The addition of a partial enclosure across half the front-facing swept area has been suggested to improve the coefficient of performance, but it undermines the multidirectional functionality. To quantify its potential gains and examine ways to mitigate losses of unidirectional functionality, we designed a Savonius blade VAWT with an independently rotating enclosure with a passive tail vane control. After analyzing the output of the system under various conditions, we conclude this particular enclosure shape drastically reduces the performance of a VAWT with Savonius blades. However, the passive tail vane rotated the enclosure to the correct orientation from any offset position, enabling the potential benefits of an advantageous enclosure design in multidirectional wind environments.

Advisor: Brian Savilonis

Design

VIV Wind Harvesting

Robert Correa, Eric Cremer, William Sweeney, Sarah Thomson

There is a need for renewable energy sources to be more feasible. The purpose of this project is to develop a compact device that is able to harvest wind energy and transform it into electrical energy using the concept of vortex shedding. When calibrated correctly, the vortex shedding will induce resonant oscillation. Electricity would be collected from this oscillation using a magnet and coil assembly. This method was proven to work in water, but has not been applied to air currents. This team designed and built a small-scale prototype to be tested in WPI's closed circuit wind tunnel. The wind harvester works at a moderate wind range of 5.4 to 6.6 m/s. Data was collected on the amplitude and frequency of motion of the cylinder during its lock-in condition. Calculations were done to find position, velocity, and acceleration of the system over a complete cycle. The results demonstrate a potential for vortex induced vibration to be utilized with wind to create electricity, however it will be difficult due to the low density of air compared to other fluid mediums, such as water.

Advisor: Brian Savilonis

Design

Electric Motorbike with Regenerative Braking

Kevin Antalek, Anthony Cangello, Matthew Chase, Micah Flock

The objective of this MQP was the design and manufacture of an electric motorbike with regenerative braking. The intention behind this was to show that regenerative braking is a cost effective way to increase the range of an electric motorbike in an urban setting. This motorbike was engineered for city use in order to test for a measurable amount of regenerative braking efficiency. The bike was designed for compatibility with electric vehicle charging stations found in most major metropolitan areas. Our group has concluded that regenerative braking is an effective means for extending mileage of an electric motorbike.

Advisors: Kenneth Stafford, Alexander Emanuel (ECE)

Design

Alternative Snowboard Binding

William Feraco, Trevor Haijko, David Trujillo

The goal of this project was to design, fabricate and test a system that would provide snowboarders with an alternative riding experience. Our prototype consisted of a top plate, bottom plate, and a roller bearing, that can attach to any board allowing for free rotation of the feet between a given degree of freedom. The plates were designed in SolidWorks, while the CAD system Esprit was used with a three axis CNC machine to cut the Nylon 6/6. Bending and torsional strain tests were performed to make sure the snowboard's dynamics were not affected. A tensile test was performed on the threaded inserts and Nylon plates to find the maximum load before dislodgment. The final test was held at a ski area to determine the safety and functionality of the design under real life conditions.

Advisor: John Sullivan

Design

Contact Lens Assistive Device

Elizabeth Dufresne, Emily Miner, Kristen Schleier

The process of inserting contact lenses can be arduous for a person with an upper-limb amputation, limited mobility in their arms, or sensitive reflexes. Enabling amputees to wear contacts can help them return to a state of normalcy after a traumatic experience. Our project team pursued three different designs for devices to hold open the eye so that contact lenses can be inserted with only one hand. We developed and refined working prototypes of each based on our design constraints related to comfort, adjustability, portability, and most of all, safety. With approval from the Institutional Review Board we were able to test our devices on WPI community members to get feedback and make improvements.

Advisor: John Sullivan

Manufacturing Engineering

Door Redesign on Caterpillar 980H Loader for Access to Oil Filter and Maintenance

Jessica Prashaw, Peerapas Thongsawas

Caterpillar Inc. is a worldwide leader in earth moving machinery, with locations in over 180 countries. In Collaboration with Shanghai University the team redesigned the access system housing the oil filter on a 980H Mid-Sized Loader. The current access system was unable to open fully, due to a space constraint issue, making routine machine service difficult. With close detail to ISO specifications, safety concerns and consumer needs four detailed designs were developed using Soildworks, and presented to Caterpillar for review and feedback. The final design was chosen using a design matrix based off of Caterpillar's pugh matrices and was a custom double slider-crank mechanism. After final section the design was then optimized for overall performance, cost and life expediency.

Advisors: Yiming (Kevin) Rong, Amy Zeng (IE)

Sponsor: Caterpillar, Suzhou, China

Materials Engineering

Determining Limitations of Kinetic Models for Pyrolysis Simulation of Fiber Reinforced Polymer Composites through Zero-Dimensional Testing Using TGA & DSC

Brianna Gillespie, Mary Long, Natalie McMillan, Caitlin Walde

Recently the fire protection engineering community has started to use comprehensive pyrolysis models to analyze the thermal performance of fire resistant polymers. In order to use these pyrolysis models material kinetics must be understood. This study evaluated recently proposed simplified kinetic modeling and analysis techniques. Samples of differing resin to additive ratios, which are representative of fiber reinforced polymers, were evaluated by Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC). The approach was to examine the contributions of the resins and additives separately in order to evaluate if the thermal properties of the respective mixtures could be predicted. The various analyses suggest that transport effects take place due to different sample morphologies and that the heat of decompositions could be combined to calculate the heat of each mixture. It was determined that models can be applied, however the type of material and the sample morphology affect the accuracy.

Advisors: Nicholas Dembsey (FPE), David DiBiasio (CHE)

Sponsor: Kreysler and Associates

Materials Engineering

Prediction of Fire Test Performance Based on Varying FRP Resin/Fire Retardant Additive Ratios

Cristina Herrera, Jerome Anaya, Daniel Morgan

The use of Fiber Reinforced Polymers (FRPs) for architectural applications in the construction industry is subjected to several requirements of the International Building Code: ASTM E84 and NFPA 285. These large scale tests can be costly and detrimental for the development of new FRP systems. These FRP systems use differing ratios of resin and fire retardant additives. How these differing ratios affect performance in ASTM E84 and NFPA 285 are investigated. This study further develops a set of screening tools based on flame extension and flame spread models to predict fire performance. These tools use data from the bench scale Cone Calorimeter to measure material fire characteristics. These characteristics are then used as input for the screening tools to estimate ASTM E84 and NFPA 285 performance. The predicted changes in performance based on changes in resin to fire retardant additive ratios are reported.

Advisor: Nicholas Dembsey (FPE)

Sponsor: Kreysler and Associates

Materials Engineering

Thermal and Electrical Transport

Jeffrey Havill, Steve Thuo

The goal of this project was to design, build, and validate a high-resolution apparatus to measure thermal and electrical property changes in heat treatable aluminum alloys. These property changes were caused by the formation and growth of precipitates during the artificial aging stage of the heat treatment. In-situ and ex-situ experiments were designed for two precipitation strengthened aluminum alloys (wrought 6061 and cast 319) to capture and quantify changes in both thermal and electrical conductivity. Measurements were made at different stages during the artificial aging process to understand the effects of precipitates size and distribution on the resulting transport properties of the materials. A comparison of the results from the in-situ and ex-situ experiments was also performed. The selected alloys will also indicate differences in thermal and electrical properties due to the presence of secondary phases (eutectic Si particles). The developments and findings in this study will be presented and discussed

Advisors: Germano Iannachione (PHY), Diana Lados

Materials Engineering

Quantitative Corrosion Evaluation and Damage Modeling in Ferrous Materials

Khalil Badran, Jaime De Souza, Joshua Morales, Eric Plante

Corrosion is the leading cause of material damage. Quantitatively measuring corrosion effects and understanding the mechanisms are crucial to predicting/modeling this phenomenon and preventing it. The goal of this study is to develop a reliable testing and analysis methodology that allows quantitative evaluation and further prediction of corrosion damage in ferrous materials. To achieve this goal, a testing apparatus was built, and a relationship between corrosion rate and sample volume, environment, temperature, agitation, and time was uniquely created. Stainless steel samples were studied in a saline solution using two standard testing methods with various conditions. The changes in mass were measured, and an original optical methodology for both surface and cross-section damage evaluation was established. Over time, the change in mass showed an asymptotic decrease, whereas surface area damage increased asymptotically. An analytical relationship between corrosion rate and various controlling parameters was ultimately developed for damage prediction in corroded materials. These results and findings will be presented and discussed.

Advisors: Diana Lados, Cosme Furlong

Sponsor: Gillette

Materials Engineering

Injection Molding of Chocolate

Jennifer Baker, Rebecca Draper, Katie Monighetti

Crystallization is vital to the texture, appearance, and taste of chocolate products. The development of ideal type V crystals is maintained through various components of the manufacturing process including tempering and temperature control. Typical chocolate is molded in gravity fed systems at a relatively low rate. The objective of this study is to examine the feasibility of injection molding chocolate to improve the production rate and textural qualities of chocolate. Samples similar to commercially produced miniature chocolate bars were produced using an injection molding machine. The textural properties of these samples were tested using XRD, DSC, and 3-point bend tests. The results indicate that the properties of the injection molded chocolate were improved from the traditional gravity fed cast molded chocolate.

Advisor: Satya Shivkumar

Materials Engineering

Processing Polylactic Acid with Bamboo Additives

Janelle Boucher, Brandon Okray

The desire for sustainable materials in recent years increased investigations into biodegradable polymers (bioplastics) and improving their capabilities with natural renewable fillers for the purpose of reinforcement. The addition of natural fillers affects processing of bioplastics due to the hydrophilic characteristic of natural fibers interacting with the hydrophobic nature of polymers. The objective of this project was to improve the molding properties of a natural fiber biodegradable composite. For this experiment injection molded samples of polylactic acid (PLA) and bamboo powder were formed. Observed distribution of the powder within the polymer and improvements in mechanical and thermal properties served as indications of processing improvements. In order to deal with the problem of agglomerations of bamboo powder optimal temperatures for the injection molder, pre-heat treatment of the samples, and coupling agents were methods utilized to minimize the effects of the clusters.

Advisor: Satya Shivkumar

Simulation of the Effects of Temperature and Time on the Tempering Behavior of Carburized Steels

Nichole Holman, Karen Paklin, Shikha Shrestha

The heat treating industry needs verified computer simulation tools to predict the carbon concentration profiles and microhardness profiles in carburized steels. Currently tools exist to predict the carbon concentration profiles for many carburization processes including endo-gas and low pressure. The models for the prediction of microhardness profiles as a function tempering temperatures and times are being developed in this project using experimental results and the Holloman – Jaffe analysis. The experimental results have shown that the hardness increases with carbon concentration and decreases with increase in temperature and time. The results of microstructural analysis will be presented and discussed in terms of phase transformations kinetics. The computer simulation will be demonstrated.

Advisors: Richard Sisson, David DiBiasio (CHE)

Robotics

Intelligent Shoe Pad for Gait Therapy

Alexander Scanlon, Adam Howard

A person's gait is defined as the manner of the legs' bipedal motion in order to achieve forward ambulation. Examples of different gaits for humans include walking, running, and sprinting. There has been extensive research conducted to measure people's gaits for gait therapy purposes, but most of the measurements need to be done periodically in an equipped laboratory. The goal of this project is to create a shoe pad with embedded sensitive electronics capable of measuring a person's gait. This "intelligent" shoe pad can be placed in a shoe to measure and store a person's gait and provide feedback to the physician on what the gait of the individual looks like in daily life. Information such as this would be highly useful for gait therapy purposes. Choosing silicon as the material for the shoe pad and force sensors for data acquisition, a shoe pad was created that could measure the weight distribution for the different sections of the foot. A computer program was similarly made to visually depict the force distribution of the foot and the gait. It was finally shown that a viable shoe pad as described could indeed be made, and utilized to gather data from the person's gait usable in gait therapy.

Advisor: Mahdi Agheli, Cagdas Onal

Robotics

BUDD-E System

Patrick Bobell, Chase Cheston, Jacob McSweeney,
Benjamin Wilson

An average of 3,533 people die of drowning each year in the United States of America, over half in rivers, lakes, and beaches, and many more survive but are left with lasting brain injury from prolonged oxygen deprivation. Distressed swimmers are rarely able to call for help or splash for attention, and often drown within 20 to 60 seconds. The primary challenge lies in immediately identifying the need for assistance and providing aid before it is too late to avoid death or permanent injury. The Buoyant Unmanned Distress Detection and Evacuation (BUDD-E) System aims to identify and rescue victims in these challenging environments, with an initial focus on crowded coastal beaches. The BUDD-E System monitors swimmers' pulses, identifies swimmers in distress, and communicates with lifeguards and waterfront safety staff in real time through a live display of all swimmers' locations on a Google Earth map of the beach. In emergency situations, an unmanned flotation robot is automatically dispatched at speeds of up to 20 miles per hour to victims for immediate support. The robot is able to transport a conscious victim to shore much more effectively than a lone lifeguard. The BUDD-E System compliments the efforts of rescue personnel in order to prevent drowning incidents and unnecessary trauma and loss of human life.

Advisor: Mustapha Fofana

Robotics

Iris: Smart Robotic Prosthetic Hand

Sean Casley, Thanacha Choopojcharoen, Adam Jardim,
Deniz Ozgoren

Though the prosthesis industry has experienced a great revolution in upper body prostheses with the introduction of advanced myoelectric grippers, users are still far from being able to complete everyday tasks with the same level of ease they once could. Complaints of available products like the i-Limb and Bebionic hand include difficulty in performing tasks due to complex user interfaces as well as a high market cost that makes the technology especially expensive to people without insurance. As a solution to these issues we propose the creation of a Smart Prosthetic Hand – a semiautonomous robotic prosthesis capable of determining the most appropriate grip for grasping an object then executing that grip.

The Smart Prosthetic Hand will be an anthropomorphic prosthesis with independently movable fingers capable of executing a variety of grips. Autonomy will be achieved through the use of a unique control system which will take input from sensors in the hand to determine the shape of an object, the position of each finger, and quality of grip. Ultimately we will work with professionals and potential users to determine whether these features make the device easier to use and more effective.

Advisors: Cagdas Onal, Taskin Padir (ECE)

Robotics

Intelligent Surveillance UAV

Andrew Gallagher, Steven Guayaquil, Benjamin McIntyre, Arianna Niro, Antonio Puzzi, Arman Uygur

Surveillance is critical for military, law enforcement, and search and rescue operations. In the past, stealth aircraft and helicopters were used for these types of missions. Recently however, unmanned aerial vehicles (UAVs) have grown in popularity and are an excellent resource that can be utilized for surveillance missions. Since there are many drones capable of this, this project sought to create a surveillance UAV that was autonomous, inexpensive, lightweight, and easy to manufacture. The drone was designed as a quadrotor that houses two cameras and a wireless transmission system that provides live feed from the cameras to the ground station. It was also designed to be able to carry a payload for future developments.

Advisor: Taskin Padir (ECE)

Robotics

Testing Platform for Flapping Wing Robots

Jesús Chung, Alexandra Beando, Kevin Ramirez,
Christopher Overton, Tyler Pietri

Ornithopters, bio-inspired systems that utilize flapping wing flight to generate lift, are a growing field of robotics with a wide range of applications. Although these bio-inspired robots are of particular interest, there are currently no successful large scale hovering ornithopters over 2kg in existence. Continuing from last year's MQP, this project developed a test bed that can effectively examine ornithopter designs and further flapping robotics research. The realization of the test bed was guided by a theoretical model developed in MATLAB. Utilizing load cells, cameras, and a LabVIEW interface, the test bed allows for the examination of different wing designs and wing motion.

Advisors: Marko Popovic (PHY), Stephen Nestinger

Robotics

Exo-Musculature

Nicholas Corso, Daniil Effraimidis, Brian Jennings,
Gregory McCarthy

The Exo-Musculature project is a novel hydraulically-actuated elastic muscle, which is inspired by the capabilities of a biological muscle. The design has certain advantages over natural muscles, such as being able to maintain a position without expending energy. This design uses an elastic element to apply tensile force, which is released when hydraulic pressure is applied. This gives the muscle the unique characteristic of storing elastic energy when pressurized and releasing it to contract. Other artificial muscles, such as the McKibben, are similar to ours in the respect that they are fluid-actuated and can be locked in place, but the McKibben requires suction or pressure to expand and contract. Additionally, our muscle is limited to expansion in only one dimension, which offers a higher energy density. It is much more compliant than traditional hydraulic cylinders, making it better suited for use in human rehabilitation and augmentation. Finally, our prototype is constructed using common materials, making it an extremely low cost solution for both medical and robotic applications.

Advisors: Marko Popovic (PHY), Cagdas Onal

Thermofluids

In Flight Recharging of Micro Aerial Vehicles

George Abbiati, John Croteau, Timothy Grupp

The flight duration of Micro Aerial Vehicles (MAVs) is frequently limited to one hour or less; often improved flight time is desired. Our project focuses on two methods of recharging MAV batteries in flight: treating the MAV's propeller as a wind turbine to regenerate energy during descent and transmitting energy to the MAV from the ground via laser or electromagnetic waves. We calculated theoretical numbers and constructed proof of concepts of these options to make appropriate recommendations.

Advisors: Isa Bar-on, Andrew Trapp (BUS)

Thermofluids

Heat Transfer into Wall Panel Connections from Residential Scale Fires

Zachary Gendreau, Nicholas Martin, John Morrissey, Trevor Rancourt

Construction of homes and buildings using panels manufactured off site is a growing method of pre-fabrication. Known as panelized construction, this method of building assembly has gained popularity in recent years. With this increase in use, the need to learn more about the fire performance of panels is crucial. The connections at which these panels come together are of particular interest. The long term goal of this work is to numerically simulate connection performance based on an assumed orientation and material properties. This project uses inert materials in physical models as well as a commercial conduction code to study heat transfer into the connections. Inert materials allow for a close match between the physical model and the conduction code. Several of the most commonly used connection orientations were exposed to residential scale fires. The heat transfer measured in the physical models was compared to that simulated using the conduction code. These comparisons will be presented in the context of evaluating the ability of the conduction code to simulate connection heat transfer.

Advisor: Nicholas Dembsey (FPE)

Thermofluids

Smoke Flow Through Exterior Assembly Construction Gaps

Jared Harbold, Brendan Kerrigan, Camille Levy, Sarah Meehan

Rainscreen cladding systems are becoming popular in building façades due to their ability to protect the building from extreme weather conditions. These systems are generally composed of several pieces assembled leaving horizontal and vertical gaps, allowing for thermal dilatation. In these kinds of façades, air may flow through the gaps into the space behind the façade, allowing for thermal, ventilation, and moisture control advantages. However, scarce knowledge is available about the fire behavior of these façade systems, and the effect of these gaps. The project aimed to characterize the fraction of the fire plume which may flow through gaps under external fire attack. Through temperature, velocity, and heat flux measurements in an *ad-hoc* designed gap assembly, the characterization of the plume fraction flowing through the gap is provided. How this gap flow effects design rules for preventing the possibility of exterior fire propagation behind rainscreen cladding will be explored.

Advisors: Nicholas Dembsey (FPE) Umberto Berardi (CEE)

Sponsor: Kreysler & Associates

Thermofluids

Thermoelectric Management of Lithium Ion Batteries in Mobile Devices

Edward Allison, Jeffrey Paquette, Philip Radder

As mobile devices continue to package an increasing number of features into smaller form factors, it is crucial to extend battery life, which could be achieved by thermal management. Efficient battery usage through overcoming thermal constraints enables the continuous improvement of device hardware and device computational power. Potential solutions to thermally manage lithium ion batteries currently exist, such as micro heat pipes, phase change materials, and nanocomposites. This project used analytical, computational, and experimental methods in parallel in order to identify characteristics of thermal management systems. These characteristics were investigated through the use of uncertainty analysis and one-dimensional models, solid modeling and FEA for three-dimensional heat flow, and wireless control of a Peltier system through an Arduino board to control battery surface temperature. Results obtained can be used in the development of potential thermal management systems for incorporation in future portable devices.

Advisor: Cosme Furlong

Thermofluids

Design of a Stirling Engine for Electricity Generation

Hongling Chen, Shawn Czerniak, Enrique De La Cruz,
William Frankian, Gary Jackson, Alula Shiferaw, Evan Stewart

The aim of this project was to design, build, and test a Stirling engine capable of generating between 200-500 watts of electricity. Several designs were studied before settling on an alpha type configuration based around a two-cylinder air compressor. Concentrated solar energy was considered as a potential heat source, but had to be replaced by a propane burner due to insufficient solar exposure during the testing timeframe. The heater, cooler, regenerator, flywheel and piping systems were designed, constructed, and analyzed. Instrumentation was built into the engine to record temperatures throughout the assembly. Several tests were performed on the engine in order to improve its running efficiency, and critical problem areas were isolated and addressed.

Advisor: John Sullivan

NOTES


WORCESTER POLYTECHNIC INSTITUTE
1865
WPI