Name(s)

Ansel Austin

Project Number

S0301

Project Title

Clean Water for All: A Novel Filtration and Maintenance Mechanism for Improving India Mark II Water Pump Performance

Abstract

Objectives

There is a widespread and urgent need to improve the quality of water that hand pumps, such as India Mark II, deliver. To achieve this, a filtration mechanism must be designed to purify pumped well water of dangerous contaminants. This device will potentially be used in the many India Mark II pumps throughout the developing countries that still rely on mechanical hand pumps for drinking water, such as India, Ghana, Uganda, and many others. By removing a secondary purifying process, communities will be able to get clean water directly from the pump, thereby reducing health risks. To address this problem, my goal was to design and prototype a filtration and filter-flushing mechanism that eliminates at least 99% of bacteria and protozoa utilizing an Ultrafiltration (UF) hollow fiber membrane and satisfies VLOM requirements.

Methods

After having assembled and installed India Mark II water pump at school with the help of my mentor, Mr. Stephen Huber, I did the initial research, took pump measurements, and performed calculations. I then designed the filtering and filter back-flushing mechanisms using Autodesk Inventor. I 3D-printed the two initial prototypes, and assembled the filtration and back-flushing mechanism utilizing Renovo UF hollow fiber membrane filters, custom laser-cut gaskets, a steel rod, and tubing. I manufactured the third, working prototype using a CNC machine, tested the water pressure and flow rate, as well as the resulting water quality. My school mentor helped me with the pump assembly and installation, operating the CNC machine, and advised me on the VLOM requirements for a community hand pump.

Results

The resulting filter with a filter-flushing mechanism is a working prototype for a filtration system, which meets the specified goals and constraints and can be installed in the India Mark II pump stand in order to purify well water, providing a low-cost and low-maintenance way of delivering safer water for the community.

Conclusions

It is feasible and desirable to modify India Mark II hand pumps with this novel filtration and back-flushing mechanism in order to significantly improve water quality and eliminate serious health risks associated with well water contaminants. While further development is needed to take this design to an industrial level, it meets the design constraints and can potentially improve the health of many communities worldwide.

Summary Statement

I designed, prototyped, and tested a novel filtration and back-flushing mechanism to improve the quality of water delivered by India Mark II hand pumps, which are used by communities worldwide.

Help Received

One of my mentors at school, Mr. Stephen Huber, helped install the India Mark II pump at school, advised me on the VLOM requirements, and trained me in using a CNC machine. I did all the calculations, CAD, manufacturing, assembly, and testing by myself.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Ryan Beam

Project Number

S0302

Project Title

Developing a UAV Free Fall Device for Microgravity Experiments

Abstract

Objectives

The objective of the project was initially to design and build a "submarine free fall vessel," this proved unfeasible. The objective then became to use the data collected from this failed project to create a completely self-contained vessel which could ascend to approx. 100m, and sustain free fall through the atmosphere for 3-4 seconds.

Methods

Laptop computer with Solidworks Student Edition CAD program, 3D Slicer, 3D printer, PLA filament, Arduino, Stepper Motors and Drivers, assorted quadcopter components.

Designed streamlined body, designed fittings for individual components, printed, built device. Tested, repeated.

Results

By way of an iterative design process, I was able to successfully build a device capable of ascending to a height of about 75 meters, then freely fall through the atmosphere for a period of just over 1.5 seconds, creating an environment suitable for microgravity experiments. I am still in the process of optimizing the device.

Conclusions

I built an inexpensive, accessible device capable of sustaining free fall conditions for several seconds. By using CAD and 3D Printing, I was able to create an ideal environment for carrying out microgravity experiments.

Summary Statement

I created a drone-like device which can be used to carry out microgravity experiments in conditions rivaling those of a traditional drop tower.

Help Received

None. I designed and built the device by myself.

Name(s)

Patrick Benz; Andrew Frohling

Project Number

S0303

Project Title

Using the Venturi Effect to Optimize the Efficiency of an Air Conditioner Condenser

Abstract

Objectives

The objective of this project is to create a way to move air more efficiently using the Venturi effect by a data driven design of optimizing venturi structures.

Methods

We used various tube dimensions, a fan and a DC power supply. We created a system in which air is moved via a fan and is accelerated through fluid mechanics principles of the venturi effect.

Results

By optimizing 4 independent variables, our system of fluid movement was 6% more efficient than that of a high efficiency residential 2 ton air conditioner.

Conclusions

We built a structure for moving fluid(air) that is more efficient than that of a standard air conditioner. Using our measurements of the ideal dimensions of the variables of our system, one would be able to create a significantly more efficient air conditioner condenser.

Summary Statement

Our project uses a fluid physics principle in order to reinvent the structure of an air conditioner, making it more energy efficient

Help Received

My partner and I designed the experiment ourselves but received help understanding the concept of the Venturi effect as well as giving us a DC power supply from out mentor, Pat Benz.

Name(s)

Tyler Billman; Anurag Gajaria; Briana Marquez

Project Number

S0304

Project Title

The Optimization of the Mechanics of a Robot

Abstract

Objectives

The primary purpose of this project is to use physics and mechanical engineering concepts to produce a multi mechanism machine with the highest calculated ideal and experimental efficiency. We combined the concepts of gear ratio, torque, levers, and ideal mechanical advantage to essentially optimize the mechanism implemented on our robot/machine.

Methods

Our first design was made as a base model that would then be adjusted to increase efficiency. The base model was constructed of steel metal parts, a ball shooting mechanism, an elevator like mechanism, and a lifting mechanism. We used several robotics competitions as our test grounds to see how the complete product would work. The first design failed, the motors burned out due to excess weight and not enough force. From that first design we simplified and modified our machine, changing out the type of metal to reduce the overall weight of the design as well as calculating the ideal mechanical advantage of each mechanism to idealize the entire machine. Using a specific equation we predicted the mechanical advantage of each design and after our test runs we were able to calculate the efficiency of the design and then modify to increase that efficiency.

Results

After the several robotics competitions, observations, and modifications, it was concluded that the most successful machine was an aluminum and steel design with less and more simple mechanism. Our final machine consisted of both aluminum and metal parts, with only a drive train and a claw which were both made most ideal using both calculations and modifications to adjust to the objective of the robot.

Conclusions

These mechanisms directly correlates to several engineering disciplines, from bioengineering, mechanical engineering, to robotics. Our experiments revealed how simple it actually is to make everyday machines more efficient, with the knowledge of the simple algebra that goes into these concepts anyone could modify their machines according to their preference or need. It is these concepts and mechanism that are used to make such innovative machines as a prosthetic robotic arm, such simple concepts that can produce machines that improve everyday life.

Summary Statement

This project utilizes physics and mechanical engineering concepts, specifically gear ratio, torque, levers, and ideal mechanical advantage, to produce a multi mechanism machine with the highest calculated ideal and experimental efficiency.

Help Received

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Tyler Bodenhamer

Project Number

S0305

Project Title

Engineering a 3D Printer Built with Recycled Computer Parts

Abstract

Objectives

My design objective is to build a quality 3D printer out of recycled computer parts, for less than $75. The 3D printer will be evaluated by comparing a 3D printed object to the same object printed on a commercially available 3D printer.

Methods

Three recycled CD-ROM drives were used for the X, Y, and Z-axis movement of the printer, along with a recycled CPU power supply. An Arduino Uno and stepper motors boards controlled both the CD-ROM drives and a rewired 3D pen extruder. Open-source programs were used to draw a 3D object, create the G-code, and then to 3D print the object. The printer settings were tested and calibrated to make the 3D printer work. A variety of shapes were printed to test quality, ease of use, and maximum print size. An identical object was printed on a commercial printer for comparison.

Results

I successfully built a functioning 3D printer for only $70.11 that can print multiple different shapes. Building and calibrating the printer took a lot of trial and error to get the printer to work well. Also, the G-code had to be edited for each object design printed. The control of the 3D pen was limited and using it as the PLA extruder was the biggest challenge to the quality of the print. The maximum 3D print size was 37 x 40 x 25 mm.

Conclusions

I was able to successfully build a functioning 3D printer for less than $75, which is much less than the cost to buy one. The final 3D print was not as crisp as the same object printed on a commercial printer, however, I believe that the print quality could be improved with further modifications. This 3D printer was very challenging to build but it shows that the basic fundamentals of 3D printing are simple to understand.

Summary Statement

I built a functioning 3D printer for less than $75 by using recycled computer parts, an Arduino Control board, and open-source software.

Help Received

I researched and built the 3D printer myself. Mr. Gonia, my engineering teacher, helped me print a comparison object on the 3D printer at my school.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Ryan Brown

Project Number

S0306

Project Title

Water Well Perforations and Their Impact on Well Efficiencies

Abstract

Objectives

The objective of this project was to determine if the type of perforations of a water well casing would determine the efficiency of the yield of a water well.

Methods

Constructed two well models using the following materials: 4 ?Carbon steel wire wrap casing, 4?Polyvinyl chloride carbon mill slot casing, 1000 pounds Quickrete all-purpose gravel,flow meter,Two Fifty-five-gallon drums, 3 cubic feet of Number three fine sand (Filter Pack), 1/2 irrigation Tubing and a Tape measure.

Proceeded to test each well by inducing water into the formation and measured the amount of water yielded in each well model to determine which well was more efficient.

Results

The PVC casing with mill slot perforations yielded .71 gallons per test, while the mild steel wire wrap casing yielded .69 gallons per test. This clearly shows that the type of perforations did not affect the yield of water inside the well. The results indicate that perforation type is not a significant factor in the yield of a water well.

Conclusions

Through my knowledge gained from this experiment I have found that both perforations are equally efficient. I also learned through my research that there are several types of perforations and types of material that can be used for well casing. When putting in wells either material would benefit its users. Since both types of perforations are equally effective you would have to consider other factors when constructing a water well.

Summary Statement

I compared wire wrap casing to mill slot casing to determine which one would make a more efficient water well.

Help Received

My dad helped me gather research sources as well as overseeing my construction of the models.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

William Chung

Project Number

S0307

Project Title

Manipulating Concentrations of Plant-Based Starches to Optimize Durability for Use in Biodegradable Plastics

Abstract

Objectives

Obtaining the most durable biodegradable plastic in terms of tensile strength and water resistance by utilizing combinations of several plant-based starches.

Methods

Tested the tensile strength of the biodegradable plastic by devising a system where one side of the plastic is attached to a stationary object and the other is attached to a bucket holding weights. By placing more and more weights in the bucket, I could tell at which point the plastic would break and record the amount of weight. Tested the water resistance by placing the plastic on top of a cup and placing water in the center. The amount of time passed before the water fell through was recorded. Used a homemade compressor to get plastic to uniform thickness and size.

Results

When comparing seven different types of starches, using potato starch had the greatest relative tensile strength and using tapioca starch had the greatest relative water resistance.

Conclusions

These results suggest that when producing biodegradable plastics, it is best to use potato starch for its high tensile strength and tapioca starch for its high water resistance time. This could be later on used for biodegradable plastic products such as bags, aiding in the resolution of environmental problems.

Summary Statement

I used different types of starches to create a biodegradable plastic and tested which would produce the most durable product.

Help Received

I used the internet to research about the different properties of starch and how biodegradable plastic is made. I used this information as a basis for my experiment. I did not receive any help from mentors/ teachers.

Name(s)

Jason Co

Project Number

S0308

Project Title

The Multipurpose Prosthetic: Using 3D Printing to Create Various Attachments for Amputees

Abstract

Objectives

Throughout their daily lives, amputees have trouble performing various tasks that we simply overlook or take for granted. Activities such as operating a computer can become difficult when losing the ability to use an arm. The objective of this project is to help amputees by creating task specific interchangeable prosthetic attachments.

Methods

Last year my teammate Sohan and I had created a makeshift prosthetic by cutting the bottom of a plastic water bottle to simulate a body powered prosthetic. We created a 3D printed adapter which attached a quick disconnect drill chuck onto the bottle cap. This allowed us to create attachments that would have hex bits connected to them in different ways. By extending their arm, the amputee would be able to disconnect and reconnect attachments with ease using a common body powered mechanism.

This year I wanted to incorporate electronics into the project in order to add more capabilities to the attachments. I created a 3D printed wrist in place of the water bottle to showcase how the drill chuck would attach to a 3D printed prosthetic. I used a Myoware myoelectric sensor to detect a flexed muscle in the forearm called the wrist flexor, a muscle that flexes when squeezing the hand. I create a computer mouse attachment so that amputees would be able to move and left click the mouse with their prosthetic arm. Assuming that the person was not a double amputee, this would allow them to use the keyboard with their uninjured hand (typing, gaming).

Results

Participants reported an average of 70% of their clicks registering to the computer. Through testing, I discovered that the success rates of the myoware differed for each person. While person C was able to use the attachment without trouble, person D had trouble even clicking once. The project was partially successful, but the consistency of the attachments needs to be higher to meet the criteria.

Conclusions

Although still in the prototyping phase, the myoelectric mouse attachment was still able to complete its job. Many amputees stated that at some point during testing they had trouble with the Myoware muscle sensor. In the future, I plan to adjust the gain values and play with the sensor so that the data output is accurate.

Summary Statement

The multipurpose prosthetic is a quick disconnect prosthetic that allows amputees to switch attachments with ease by simply extending their arm. The goal of the project is to assist amputees in their everyday lives by creating cost effectiv

Help Received

I designed and created the prosthetic attachments myself. I contacted clinical biomedical engineers Brian Burkhardt and Seth Hills for feedback on my project via email

Name(s)

Kayla Cunningham

Project Number

S0309

Project Title

Using Winglets to Reduce Drag, Therefore Decreasing Fuel Consumption and Carbon Dioxide Emmissions

Abstract

Objectives

Create a winglet that has the ability to reduce drag more effectively than the winglets that are currently being used on airplanes.

Methods

Autodesk Fusion 360 to design the new winglets, a Tronxy 3D printer to make them, and a wind tunnel. Compare the measured movements of the new winglets created and the ones that Boeing currently uses.

Results

All the wings were tested in the wind tunnel several times (to ensure accuracy) on a pivot system of my design. When the trials of the winglets I created were compared to the trials of the previously existing winglets, one of my designs (the triple winglet) was found to reduce the most drag.

Conclusions

I found that the triple winglet that I invented reduced the most drag because it was the slowest to move on the pivot system in the wind tunnel. This means that the triple winglet can make airplanes more efficient.

Summary Statement

I created a winglet that reduces drag on airplanes more efficiently than winglet designs that are currently being used.

Help Received

An internet search helped me understand the concepts behind winglets and guided me in building my wind tunnel. I designed the winglets and wind tunnel pivot system on my own.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Sofia Echavarria

Project Number

S0310

Project Title

Better Helmets, Fewer Sports Related Concussions?

Abstract

Objectives

My goal was to engineer a helmet that would lower the g-force of an impact which could prevent or decrease concussions in soccer (and other sports). I identified the problem that there are few options or helmets that prevent and/or reduce concussions for soccer players yet receiving a concussion is very common (18% of injuries in high school soccer are concussions).

Methods

I created four different cardboard prototypes based on my own research of animals and other work. For the prototypes, I also used foam, metal springs, plastic packing air bags, and rubber bands. I wired, soldered and programmed a 200 g Arduino accelerometer. For programming, my mentor Dr. Frewen helped me code the internet version to show the highest g-force felt on impact. For the final draft, I designed and 3D printed the main shells and pieces of the prototype. I also lasercut extra pieces on a laser cutter to fit in additional pieces that the 3D printer could not print correctly. I designed and cut these pieces on my own. I then used a soldering iron and 3D printing filament to assemble the final draft helmet.

Results

I used four prototypes, each using a different material and/or system, and one control with no extra material (just cardboard). The four materials in the prototypes were rubber bands, air bags, foam, and springs. I tested the prototypes with two methods: (1) dropping the prototypes from different heights (1-2.5 ft) and (2) dropping weights on the prototypes (50-200 grams). I placed the arduino under the prototype, ensuring the prototypes were hit with the force of impact first. According to my research, a concussion results from 95 g-force (Gs) to the body. I determined that three of my prototypes were most effective in minimizing the g-force of the impacts: the air bags, foam, and springs. I used the foam and spring contraption to make the final prototype and that was the most effective out of all of the prototypes in minimizing g-force.

Conclusions

I learned that a combination of foam and springs to absorb the g-forces were most effective in reducing g-force to a head or object receiving impact. My final prototype used both foam, springs, 3D printed pieces, and lasercut pieces and the results showed it succeeded in reducing g-force. This information could be used to create a helmet that can be used to reduce concussions in soccer. There are few options for helmets to prevent concussions in soccer and many have no evidence demonstrating that they work. By reducing the g-force of an impact on a soccer player's head, my prototype could give soccer players a chance to return to soccer more quickly after a concussion because it lessens the injury, or could even prevent concussions

Summary Statement

I created a helmet that minimizes the g-force of varying impacts in order to reduce concussions in soccer players.

Help Received

I did all of the work myself but Dr. Frewen helped me with troubleshooting the arduino when I couldn't figure it out and with teaching me how to 3D print.

Name(s)

Caitlin Gorin

Project Number

S0311

Project Title

A Multi-Faceted Material Strength Testing Machine for 3D Printed Plastics

Abstract

Objectives

Today there is a need to understand the strengths of 3D printed products given the recent decreases in 3D printer prices and increase in start-ups 3D printing their products. Professional Universal Test Machines (UTM) can be used to test material strengths; however, they tend to be large and expensive. The objective of this project is to create an affordable, multi-faceted, re-configurable, material strength testing machine that can conduct a variety of different strength tests: Tensile, Flexure, Compressive, Shear, and Layer Adhesion.

Methods

The Testing Machine was designed to conduct 4 Strength Tests in accordance with ASTM standards (D638 - Tensile, D790 - Flexure, D695 - Compressive, and D5379 - Shear) as well as a newly developed test, Layer Adhesion. ASTM does not have a standard for testing Layer Adhesion Strength of 3D Printed Plastics.

The Testing Machine includes an all metal frame, a load cell, 2 stepper motors, an OLED, a MicroSD, 4 Test Fixture Set-Ups, and an Arduino-MEGA with home-generated open-source software using both I2C and SPI protocols. Materials tested were PLA, ABS, and PETG. For each of the materials, 5 Test Specimens were 3D printed and tested for each of the 5 Strength Tests. Specimen geometries were derived from ASTM standards.

To conduct each test, a Test Fixture and a Test Specimen were mounted to the Testing Machine. The test direction (Up/Down) was selected and the Testing Machine powered on. The Stop Button was pressed when the Test Specimen broke or the motors stopped turning. Power was turned off and the data retrieved from MicroSD Card for analysis. For each run, 3 pieces of information was collected - Step Number, Time, and Load Value. The machine was then reset to continue testing for all the materials and test configurations.

Results

Load data was used to determine Yield levels and corresponding Moduli s for each Strength Test was calculated. Data plots for each test were consistent and correlated across materials. For the material Strength Tests, PLA was the strongest, followed by ABS, and PETG. PETG was the most flexible; this was consistent with its lower Modulus of Elasticity values.

Conclusions

This project was declared a success. The Multi-Faceted Material Strength Testing Machine successfully demonstrated 5 different Strength Tests using 3 different materials; used readily available, low cost components; and incorporated electrical, mechanical, and software design aspects. This Material Strength Testing Machine is ready for a small start-up to test their 3D printed products' materials strengths.

Summary Statement

Developing and demonstrating a stand-alone, low cost, open-source, reconfigurable, adaptable, universal test machine (UTM) for strength testing of 3D printed plastics.

Help Received

My father purchased the components and materials that I identified for this project. A local sheet metal shop helped bend the flexure test fixture pieces.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Ashutosh Kandala

Project Number

S0312

Project Title

A Novel Approach to Reducing the Amount of Headfirst Injuries on a Bicycle

Abstract

Objectives

The objective of this study was to design a self-contained airbag that reduces the impact of over-the-bars crashes. The airbag was intended to be embedded in the stem of a bike so it would be easily interchangeable.

Methods

A spring-loaded nail, activated by nichrome wire, was used to puncture the CO2 canister required to inflate the airbag. A gyroscope sensor along with an ATMega 328 micro-controller was used to automatically inflate the airbag when the bike reached an angle between 20 and 30 degrees relative to the ground (simulating a fall). The code run on the microcontroller was entirely self-developed. Different sizes of airbags(40cm X 60cm & 60cm X 82 cm) made of ripstop nylon, were used for testing. A pressure sensor was placed within the airbag to note the rate at which air escaped. The GL248 code for the pressure sensor was used from http://science.cleapss.org.uk. The impact of the rider on the airbag was tested by replacing the seat post of the bike with a wooden dowel attached to a soccer ball with a helmet on it. An FSR sensor was placed between the soccer ball and the helmet to measure the impact pressure. The code for the FSR sensor was used from https://learn.adafruit.com/force-sensitive-resistor-fsr/using-an-fsr

Results

The results showed that the effectiveness of the airbag was extensive. When the impact on the airbag was tested, compared to the impact on the bare ground, the force (in newtons) on the head was minimized by over 50%. Between the different sizes of airbags tested, the airbag that consistently showed a better impact reduction rate was 40cm X 60cm. This airbag also repeatedly inflated between 0.3 and 0.4 seconds when activated. The inflation mechanism was successfully activated 95% of the time. Furthermore, the airbag successfully inflated when the bike reached an angle of 20 to 30 degrees relative to the ground.

Conclusions

This study allowed for the creation of a fully functional prototype of an airbag that could be embedded in a bicycle stem. The inflation mechanism designed in this experiment introduced the airbag-level inflation mechanism that can prevent injuries. The results of this experiment can be used to further research as to how over-the-bars injuries can be prevented using airbags embedded in bikes

Summary Statement

I created a self-contained airbag embedded in the stem of a bike that reduces the impact of over-the-bars crashes by over 50 %.

Help Received

I designed, and preformed prototyping by myself. My parents helped to supervise me when dealing with dangerous materials. My science teacher reviewed my final abstract and results.

Name(s)

Spencer Krock

Project Number

S0313

Project Title

Wind Tunnel Analysis of Semi-Rigid Airfoil Structures for a Collapsible Hybrid Buoyant Atmospheric Spacecraft

Abstract

Objectives

The goal of the research was to identify potential internal support rib designs for a collapsible, hybrid-bouyant spacecraft wing structure, when covered by a flexible material like Mylar, may more efficiently provide long term-sustained flight in another planet s atmosphere.

Methods

Based on previous research utilizing a scale model of a proposed spacecraft, it was determined that a 10cm wing segment with the average chord length of the full 1-meter wingspan wing would act as a representative model for this study. The 10cm wing segments were built with different numbers of 3D-printed internal ribs to provide different amounts of support to the covering. The NACA 4421 airfoil shape was selected as the cross-sectional design for the test segment ribs. A wind tunnel from California Baptist University was used for generating lift and drag data for the model wing segments. The data from the Mylar covered test wing segments were compared against data from a similarly shaped but fully rigid control wing segment.

Results

It was determined that all the test wing segments had higher lift-to-drag and lift-to-weight ratios than the control wing segment. When scaled to the full 1-meter wingspan, only the wing segment with two widely spaced ribs demonstrated a weight ratio above 1, which indicates the wing could sustain flight. Additionally, a wing segment with five total ribs had a maximum approximate lift-to-drag ratio of 3.5, meaning it was the most efficient at generating lift relative to the amount of induced drag.

Conclusions

The study sheds further light into the design of a collapsible, hybrid-buoyant wing for flight on a high-density atmosphere planet, such as Venus or Jupiter. With the discoveries made with the two-rib wing segment, further experimentation into different airfoil designs and optimizations of wing volume will guide further development efforts to make the wing more efficient for both compacting for launch and expanding for atmospheric flight.

Summary Statement

My research has shown that an internal wing design containing a flexible skin and multiple ribs has the potential for long-term sustained flight for an atmospheric-based spacecraft to collect data on another planet.

Help Received

Dr. Daniel Clark assisted in clarifying aerodynamic concepts and supervised wind tunnel experimentation. Dr. Kevin Krock assisted in 3-D printing and wing assembly.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Shreya Kumar

Project Number

S0314

Project Title

Self-Stabilizing Tensegrity-Inspired Robotic Leg

Abstract

Objectives

When trying to imitate the natural flexibility of the human body in robotics, using a tensegrity-inspired structure is the best option. Tensegrity-inspired structures consist of rigid compression elements, which act as a supportive structure, and elastic tensile elements, which can absorb and distribute force evenly. The objective of this project was to make a tensegrity-inspired robotic leg that was self-standing and that could squat and stand up like a human leg.

Methods

The structure of our robotic leg was constructed using carbon fiber rods as the rigid compression elements, strings as the elastic tensile elements, and 3D printed pieces as the joints, constructed in Autodesk Fusion 360. An OpenSim model was used to determine the optimal muscle excitations needed to achieve the specific angular displacements of the leg when it squats. Arduino was used to code the squat and stand up functions for the robotic leg which moved actuators backwards or forwards for a certain amount of time to achieve these optimal muscle excitation patterns. This in turn, moved the attached strings backward or forward as well, creating a pulley system. A motion capturing system was used to obtain the angles of deflection of the joints when the leg squatted and stood up, and this data was plotted in MATLAB.

Results

The leg was self-standing. The experimental validation between the simulation and physical prototype verified consistent behavior between accuracy with the simulation and the prototype. The biggest discrepancies in the angular displacements were that the hip joint of the prototype was two degrees more than the simulation's, the knee joint was 5 degrees more, and the ankle joint was 10 degrees more. However, only if the differences were 20 degrees or more, then the simulation would not have been validated, and so these discrepancies were insignificant.

Conclusions

The squatting and standing up motion of the prototype is comparable to a human's. The long-term purpose of this project is to develop an assistive wearable device that utilizes tensegrity to help users with their gait. This project shows how tensegrity-inspired structures can accurately imitate motions of the human leg and can be implemented in prosthetics with higher quality actuators and materials. My contributions to the published paper were that I added images and worked on the research discussed in the paper.

Summary Statement

The purpose of my project is to create a tensegrity-inspired robotic leg that is self-standing and can squat and stand up like a human leg.

Help Received

I conducted the project in UCSC and used the resources provided. My mentor and the DANSER lab (team of undergraduates) created the OpenSim model and the positional open loop system with IMU sensors. Previous prototypes of the leg were built in my mentor's lab, which I constructed the new leg from.

Name(s)

Andrew Land

Project Number

S0315

Project Title

Investigating String-Bow Interactions on a Novel Optoelectronic Cello

Abstract

Objectives

Investigating correlations between the perceived quality of cello bows and rosins, and cello string behavior in the time domain. Novel optical sensors directly monitor the vibrations of each of string. If measurable criteria correlating subjective and objective observations can be established, then this will guide the development and evaluation of cello bows and rosins.

Methods

Individual string motion is measured using novel optical sensors mounted on the cello bridge (developed for last project). The sensor is a dual-segment photodiode placed close to the string, illuminated by a laser diode, with the string casting a shadow on the sensor. The differential signal across the photodiodes is proportional to the string displacement. Recorded audio files were reviewed for time domain signatures and also converted to frequency domain for comparison. Two different cello bows, one of perceived high quality and one basic, and three different grades of rosin were tested. Results were acquired from five cellists, each playing the same note repetitively using their own bows and the two experimental bows.

Results

Two different signatures in the bowed notes time envelope were measured to characterize the string-bow interaction. The optical sensor allowed the time of bow first touching the string to be observed and the time from first touch to initiation of a regular pattern of string motion to be measured. A correlation between this time delta and perceived bow quality was observed. The ability to maintain a consistent tone throughout a bow stroke is a key aspect of performance. For novice players the tone can break during the bow stroke. The fraction of bow strokes which showed tone breaks was noted for 5 cellists using 3 bows. A correlation between the ability to maintain a constant tone and perceived bow quality was observed.

Conclusions

An objective analysis of cello bow and rosin quality using an optoelectronic cello based on novel optical sensors has yielded promising results. Trends in the time domain behavior of string motion have been found which link the perceived quality of the cello bows and rosins to the time domain behavior of the string-bow interaction. Establishing measurable criteria correlating subjective and objective observations will provide guidance for the development and evaluation of cello bows and rosins.

With (perceived) higher quality bows and rosins, the transition time from bow touch to establishing stable tone is shorter, and the ability to maintain a stable tone is greater.

Summary Statement

Two distinct effects in the time-domain behavior of the bowed cello string show promising correlations with the perceived quality of the cello bows and rosins used.

Help Received

My fellow youth orchestra cellists provided willing bow strokes, and my dad helped with the analysis software and poster graphics.

Name(s)

Stanley Liu

Project Number

S0316

Project Title

An Integrated Microfluidic System for Blood Plasma Separation and Immunoassay Detection

Abstract

Objectives

Human blood plasma is critical for disease diagnostics since plasma contains biomarkers associated with many diseases, including those associated with viral or other pathogenic infections. The current rapid tests (lateral flow strips) are inexpensive and fast but suffer from low accuracy and manual preparation as they rely on colorimetric detection and the separation of plasma through centrifugation. The benchtop standard for plasma separation is centrifugation, which suffers from its bulky and expensive design, and inability to be integrated with detection. The objective of this project was to develop an inexpensive and efficient integrated device based on acoustic microstreaming for plasma separation and biomarker detection.

Methods

The device was completely designed by myself using the AutoCAD software. The device was fabricated on PDMS, an inexpensive polymer, at UCI lab with the help of the mentor. The device was first tested using food dyed water by myself at home. Biological tests were done at the microfluidics lab at UCI under proper safety protection using control blood and inactivated P24 antigens and antibodies (all commercially available). Any work handling the P24 antigens and antibodies was done by the mentor. The data analysis was performed by myself. A commercial software ImageJ was used to analyze fluorescent images.

Results

An integrated microfluidic device for blood plasma separation, antigen/antibody binding, biomarker capture, and fluorescence detection was successfully developed. Bubble-induced acoustic microstreaming allowed plasma to be separated from blood cells resulting in a pure plasma at the end of the separation channel. Plasma separation was demonstrated at a separation efficiency of 99.9% and a yield of 31.8%. Microstreaming was used as a micropump to achieve 6 µL/min and also a micromixer to enhance antigen/antibody mixing and binding. The fluorescent detection of P24 antibody from a whole blood control was demonstrated with a detection limit of 17 pg/µL.

Conclusions

A microfluidic device for blood plasma separation, antigen/antibody binding, biomarker capture, and fluorescence detection was successfully demonstrated. Acoustic microstreaming showed advantages over the other plasma separation techniques: 1) no cell clogging issue; 2) no moving part; 3) simple in design; 4) easy to integrate and fabricate; 5) low cost. The micropump and micromixer based on acoustic microstreaming are low-cost and efficient. The integration of plasma separation and biomarker detection could serve as a faster and more effective alternative to the current rapid diagnostic tests.

Summary Statement

An integrated microfluidic device based on acoustic microstreaming was successfully developed for blood plasma separation, antigen/antibody binding, biomarker capture, and fluorescence detection.

Help Received

I designed the entire device by myself, led a majority of the experiments, and did all data analysis. Neha Garg at UCI helped fabricate my device, supervise me during experiments, and provide advice on how to modify experimental procedures. Professor Rasheed at USC offered advice on biomarker detection.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Jaden Luna

Project Number

S0317

Project Title

Formulating a Superior Concrete while Utilizing a Roman Influence and Calcium Carbonate

Abstract

Objectives

The object of my study is to test the superiority of Roman concrete against standard Portland cement.

Methods

Cooked seashells down into calcium hydroxide, mixed with volcanic ash and aggregate/silica to make Roman concrete. Let concrete set. Tested comprehensive strength using uni-axle compression machine. Place in jars of water to test the effect on the PH of water.

Results

I found that Roman concrete isn't as strong as the control, but doesn't change the PH of water as much, symbolizing the environmental difference.

Conclusions

Roman concrete is unfortunately not as strong, however is far more environmentally stable. I concluded that Roman concrete is superior to Portland cement in most cases. The lack in strength is made up for with the incredible environmental impact.

Summary Statement

My project is aimed towards discovering the benefits of Roman concrete compared to Portland cement.

Help Received

My parents helped with the collection of materials and I received access to the materials testing lab from FSU assistant professor Dr. Kimberly Stillmaker.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Brooke McMorris

Project Number

S0318

Project Title

Archimedean Faucet: A Miniature Hydraulic Turbine

Abstract

Objectives

The objective of this project was to produce an Archimedean Screw Generator in the form of a faucet the efficiently utilized the flow of sink water to generate electricity.

Methods

I used a 3D printed Archimedean Screw to convert the potential energy of flowing water into mechanical energy, which was then converted into electrical energy by a DC motor that operated as a generator. The entire system was contained in a 3D printed prism that served as the spout of the faucet.

Results

The third prototype of the Archimedean Faucet did not generate a sufficient amount of electricity because the Archimedean Screw, which the entire electrical generation is dependent on, did not rotate. However, I discovered that Archimedean Screw rotates when resistance is eliminated from the turbine.

Conclusions

I concluded that an Archimedean Screw Generator can be efficiently implemented to a faucet as long as the turbine rotation is maintained.

Summary Statement

I designed a miniature Archimedean hydraulic turbine in the form of a faucet.

Help Received

I did not recieve any form of assistance in the research, design, or construction of the project.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Junho Park

Project Number

S0319

Project Title

Exploration of Charging Cable Durability

Abstract

Objectives

Sometimes the price of an authentic product may cost a lot more than the quality and design of the product, but consumers feel more comfortable in trusting name brands by paying the premium on finished goods. There is a deep curiosity in understanding if the product does last longer than the cheaper generic charging cables. By testing the durability of the charging cables, the quality of generic brands will last longer than the quality of the name brand since generic brands comprise of PVC materials.

Methods

1 plank wood, 2 2x4 plywoods, 1 1 x 3 plywood, 6 screws, bolts, nuts, 2 small sized brackets, 8 normal sized brackets, 2 big sized brackets, 2 expanded brackets, 2 usb type c receptacle, 2 lightning usb receptacle, 6 Ax-12A servo motors, 1 main processor, 1 battery, 6 cables, 8 OEM Samsung usb type c, 8 OEM Apple lightning usb, 8 generic usb type c, 8 generic lightning usb, 1 styrofoam, 1 power supply

Build a Testing Platform by following the steps below:
1. Install 2 2x4 plywoods in each side of the 7/32 x 23-¾ x 23-¾ plank wood.
2. Pre-drill holes on the plank wood for installation of servo motors.
3. Screw mid big sized bracket into servo motor for the flexing motion.
4. Repeat the previous step for another motor. Setting motors for the feeling 5. motion are done.
6. Install receptacle into the mid part of the small-sized bracket by melting the hole with solder stick.
7. Screw the bracket that was done in the previous step into the servo motor and attach the servo motor on to the mid-sized bracket using a spacer between the motor and bracket.
8. Repeat the previous 2 steps for another motor. Setting motors for the twisting motion are done.
9. Attach small sized bracket into the outer part of the big sized bracket.
10. Screw the bracket that was finished in the previous step into the servo motor and install servo motor into the expanded bracket using a spacer between.
11. Repeat the previous 2 steps for another motor. Setting motors for the combination are completed.
12. Install all 6 motors into the corresponding places.
13. Install mid-sized bracket onto the plywood. It should be parallel with the motor.
14. Repeat the previous step for the flexing motion and repeat 2 times for the combination motion.
16. Screw the main processor on to the bracket and screw bracket onto the plank wood.

Summary Statement

Comparing quality of name brand charging cable and generic brand charging cable by mechanical manipulation.

Help Received

Mr. Anthony Pham

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Brent Peluso

Project Number

S0320

Project Title

Electrothermally Cooling a Pitcher's Arm

Abstract

Objectives

Cold temperature therapy using ice is a common method of recovery for baseball pitchers used to reduce inflammation of the shoulder and elbow after pitching. However, ice is usually not readily available to amateur and youth baseball pitchers directly after in-game throwing. Further, the zero degree Celsius temperature of ice may not be the optimal cooling temperature to aid recovery. As is suggested by the fact that ice must not be placed in direct contact with skin and must be kept on only for short periods of time, ice is likely too cold to optimally reduce inflammation. The objective of this thermoelectric cooling device is to provide a convenient alternative to ice with the ability for the user to control the specific cooling temperature. As an additional benefit, the chosen implementation method also provides the ability to heat.

Methods

At its core, the system uses a Peltier device, which is a small, powerful solid-state heat pump, to extract heat from water. The water is cycled through insulated tubing, cooling pad, water reservoir, and water block. The heat extracted and pumped by the Peltier device is dissipated to the ambient through a forced convection radiator. The system is designed for operation from a 12 Volt battery and is controlled by an Arduino microprocessor and an H-bridge driving circuit.

Results

A prototype was built as per the above description. The prototype was tested to be able to cool down the temperature of the internal operating liquid to temperatures as low as zero degrees Celsius and to heat up to 60 degrees Celsius. The prototype was also able to regulate a user-selected temperature when applied to an arm.

Conclusions

The initial objective of creating a portable battery powered cooling/heating device was achieved. Several applications beyond a Pitcher's arm exist for this device, including general injury rehabilitation and improving human performance in suboptimal temperature conditions.

Summary Statement

This device is a cooling/heating system created to provide a more convenient, safer, more readily accessible alternative to ice that allows the user to control the temperature to both heat and cool.

Help Received

My father, who is an electrical engineer, explained to me the principles of Peltier devices and the Peltier effect as well as providing insights to creating my Arduino program.

Name(s)

Firas Qureshi

Project Number

S0321

Project Title

An Economical Microfabrication Process for the Production of a Microfluidic Device to Isolate Volvox aureus

Abstract

Objectives

Microfluidic devices made of elastomer poly(dimethylsiloxane)(PDMS) using multilayer soft lithography are used for single cell bioanalysis. My goal is to utilize a novel economical process to fabricate PDMS microfluidic device to isolate a single cell colony of Volvox aureus(green algae).

Methods

Variations in microfabrication and operational processes were done across trials to achieve optimal procedures. As a result of the combination testing, final procedures for fabrication of the PDMS microfluidic device required 6mm thickness of PDMS, clear nail lacquer photoresist, T-junction AutoCAD design, polyjet 3-D printing for the wafer, thermal bond of 80 degree Celsius, 1000 micron microfluidic channel width, 3000 micron channel inlet width, emulsification agent was vegetable oil, and utilizing vacuum desiccator. Different concentrations of water:algae, 1:1, 1:2, 2:1, were used. The number of a droplet with zero colonies, one colony, and more than one colony were recorded across five trials.

Results

The variations in the microfabrication and operational processes to achieve optimal procedures utilized different trial combinations. The standard utilized to determine the best method was if the combination produced a droplet. The best combination was used to produce a microfluidic device. The total cost of the PDMS microfluidic device utilizing the optimal procedure was $275. The 1:2 concentration water:algae produced average of 1.62 cell colonies in one droplet, while 2:1 concentration produced average of .32 algae colony in a droplet. A concentration of 1:1, water:algae, isolated one algae colony in 15/20 droplet

Conclusions

The data consistently supports the hypothesis. By using a 1:1,water:algae, in the PDMS microfluidic device, I was successful in isolating a single cell colony of Volvox aureus 75% of trials. The purpose of this experiment was to exemplify the capability of my novel process to produce a PDMS microfluidic device that could successfully isolate a cell. The variations of materials and methods used in the fabrication of the PDMS microfluidic device led me to engineer a new economical fabrication process to produce a microfluidic device that is 10% of the cost of Professional Institution microfluidic device. Not only have I been able to make a more economical device, but also proved that it functions reliably to isolate a cell colony. This novel methodology can be extended to any cells. The economical microfluidic device allows for greater access to this technology and will result in the development of advanced applications.

Summary Statement

A novel, economical process for the production of PDMS microfluidic device to isolate a single cell colony of Volvox aureus in a droplet..

Help Received

I worked independently on this project, utilizing only the laboratory space at Epinex Diagnostics.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Remy Reeb

Project Number

S0322

Project Title

Reducing the Incidence of Falls among the Elderly

Abstract

Objectives

Problem: According to the CDC, over one in four adults age 65 and over fall in a given year. Despite increased recognition regarding the negative consequences of falls and increased implementation of fall-prevention awareness and exercise programs, the rate of falls has been on an upward trend almost every year since 2002. The rate of falls in 2016 (the most recent year available) was the highest since at least 2001. Falls can result in everything from a bruised ego, to broken bones, to even death. Unintentional falls are the leading cause of accidental death for people age 65 and over.

Hypothesis: The incidence of falls among people age 65 and over can be reduced with the use of a specially designed shoe with a wider sole than a standard shoe. The wider sole will create a larger base of support and lower Center of Gravity, providing more stability and improved balance.

Methods

Procedure: This research study included three primary components: 1) a survey of elderly people regarding their experiences with falls, 2) design and construction of a life-size mannequin for testing, and 3) design and testing of fall-prevention shoes.

The fall survey asked questions covering topics ranging from the number of times fallen in the past 12 months, the nature of the falls, and the location of the falls; as well as their attitude towards potentially wearing fall-prevention shoes. 41 people were surveyed.

Initially, an attempt was made to construct a life-like mannequin with bendable ankles, knees and hips. However, the mannequin was unstable, and so a second more rigid mannequin was constructed and utilized for testing.

The test shoes included three different sole sizes: a standard women's sneaker (the most common shoe type worn when a fall occurred), and two pairs of fall-prevention shoes with a sole-widening strip of rubber adhered to the perimeter of the rim of the sole (1 cm and 2 cm widths).

Three tests to determine the effectiveness of the shoes included: 1) a Tilt test, 2) a Wobble (or oscillation) test, and 3) a Drop test. The tests included setting the mannequin in motion either forward, sideways, or backwards, and measuring the angle at which it either fell over or the extent of movement, or in the case of the Drop test, whether the mannequin remained standing or fell.

In addition, a physical therapist and two primary care physicians were interviewed for insights on elderly falls and thoughts about a fall-prevention shoe.

Summary Statement

Specially designed shoes with wider soles than standard shoes create a larger base of support and improve balance and stability which could reduce the incidence of falls among the elderly.

Help Received

My advisor, Mrs. Lopatka, provided project guidance; while Mrs. Rafie, a physics teacher at my school provided insights about balance. Regarding shoe design and effectiveness, I talked with a physical therapist and two physicians. My father helped me throughout the project.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Tyler Robertson

Project Number

S0323

Project Title

Project POWER: A Swift Water Warning System, Year Two

Abstract

Objectives

Every spring, people drown in local rivers because they underestimate the power and danger of the river flow from melting mountain snow. The purpose was to design, construct, and test Project POWER: a portable swift water warning system that alerts swimmers of dangerous water conditions.

Methods

In Year Two, the buoy was redesigned to improve its portability and visibility. A temperature sensor, radio transceiver, and additional LED lights were added to the buoy. An onshore station was also designed and built to provide local real-time display of river velocity and temperature using radio telemetry data from the buoy. The onshore station included an audio alarm, LED lights, a radio transceiver, and an LCD display. When water velocity or temperature reached a set threshold, LED lights on the buoy and station changed from green to red, and an audio alarm was elicited at the onshore station to provide both visual and audio warnings for potential swimmers at the river s edge. The buoy and onshore station both utilized Arduino microcontrollers and were powered by 12Ah batteries connected to 9W solar panels. Flow meter and temperature sensor calibrations were completed in an exercise pool with variable flow rates. Proof of concept trials were completed on the San Joaquin and Tule Rivers with two different anchoring systems, placing the buoy in the area of highest water velocity.

Results

The buoy anchoring system worked well with both the across-the-river control line and the bridge access line. Radio telemetry was effective in sending river data from the buoy to the onshore station. Audio and visual alerts responded correctly to the set threshold for both temperature and water velocity. Compared to Year One, the POWER buoy demonstrated improved flow rate accuracy in both higher and lower river currents.

Conclusions

Project POWER demonstrates the potential to save lives by alerting swimmers onsite of quickly developing unsafe river, tidal, or even flood conditions.

Summary Statement

I designed and built a swift water warning system that provides swimmers visual and audio alerts when local river conditions are unsafe (current too fast or water too cold).

Help Received

I designed, built, and programmed the prototypes myself. A member of the Tulare County Sheriff's Swiftwater Rescue team assisted with buoy placement on the Tule River. The Canoe Specialist from Scout Island assisted with buoy placement on the San Joaquin River.

Name(s)

Emily Tianshi

Project Number

S0324

Project Title

Micro-Pattern Surface Property Design for Atmospheric Moisture Harvesting: Biomimicking Torrey Pine Needles

Abstract

Objectives

Harvesting atmospheric moisture is an innovative way to help solve the world's freshwater shortages. Torrey Pine trees are well known for their moisture harvesting capabilities, but little research has been done to understand their mechanisms. After studying its surface structures and properties at a microscopic level, I identified an alternating hydrophilic and hydrophobic surface micro-pattern on the needles. I hypothesized that this alternating micro-pattern may be more efficient than a purely hydrophilic surface for moisture collecting. My goal was to find an optimized hydrophilic and hydrophobic ratio on the micro-pattern to achieve both a high moisture condensation and droplet transportation rate and understand the mechanisms behind it.

Methods

A Keyence 3D Microscope (VHX) and FEI ESEM (Quanta) were used to observe needle microstructures. To fabricate the micro-patterns, I used a Xerox laser printer (Work Centre 7225) to print hydrophobic toner (PN 006R01453) on hydrophilic transparency films (3M GC3700). To model Torrey Pine needles stomata size (20-40um), I designed vertical hydrophobic lines 40 um wide, with 3, 7, 15, and 31 pixels of hydrophilic area in between the lines. A 100% hydrophilic control was printed next to the pattern samples.

Results

The pattern with a 600um hydrophilic gap between 40 um hydrophobic lines had the highest water collection rate. It collected around 2.6 times more water than the 100% hydrophilic control. The periodic hydrophobic lines reshaped the water droplets by repelling them from expanding in a horizontal direction. The droplets could only extend in the vertical orientation, which helped them overcome the pinning force and transport down quickly.

Conclusions

This study approved the concept of applying a micro-pattern on a material surface to improve its moisture harvesting abilities through increasing the droplet transportation rate. This project has a wide range of applications, including improving current 3rd world country fog collecting devices, clothes or tents that collect moisture for areas with limited resources, self-cleaning solar panels/windows, etc.

Summary Statement

I biomimicked Torrey Pine needles' alternating hydrophilic and hydrophobic surface properties to fabricate a micro-pattern that collects 2.6 times more moisture than a purely hydrophilic surface and demonstrated the theories behind it.

Help Received

My mentor, Dr. Pao Chau from Torrey Pines Docent Society, suggested reference papers to read and reviewed my results. Peter Fellingham, my robotics coach, helped construct my vapor box after I designed a prototype. In previous years, I used an ESEM from UCSD and Keyence 3D Microscope from Cymer

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Jeffrey Wisoff

Project Number

S0325

Project Title

Assessing the Angular Dependence of Skull-to-Brain Impact Dynamics to Inform Future Bicycle Helmet Design

Abstract

Objectives

Since bicycle helmets are designed to balance both safety and comfort, testing methodologies should have adequate fidelity to measure the relevant variables. Because the brain is not modeled, current bicycle helmet testing offers no insight into the dynamics between the skull and brain during collisions, nor does it examine helmet performance at varying impact angles. By utilizing an instrumented skull-brain model, this work investigated the angular dependence of the skull-to-brain impact dynamics for 3 different helmet designs at 4 different impact angles.

Methods

A modified weight lifting machine served as a drop tower and photo sensors were used to measure the impact velocity achieved. The instrumented head assembly consisted of an anatomically correct 3D-printed skull encasing a model brain cast from 0.5% agarose gel which mimics the physical properties of the brain. 3D-printed angle brackets controlled the impact angle of the head assembly. Peak accelerations were computed from accelerometers embedded in the skull and brain for test drops from 0.5 meters. Time history data was recorded at 500Hz.

Results

The measured peak G force on the skull increased more significantly for flatter helmets than a round helmet as the impact angle was increased. The round helmet showed significant bounce or recoil effects at the highest impact angle whereas the flatter helmets showed about a 20% reduction in the transfer of the peak acceleration from the skull to the brain.

Conclusions

The measured G force variation on the skull with impact angle can be correlated to the shape of the helmet. Most importantly, the peak G force increased with large impact angles for the helmets with a flatter design. This is likely due to the initial surface area contacting the ground decreased as the impact angle increased. This result suggests that certification protocols should include testing at higher impact angles. Secondly the time evolution of the tests showed additional acceleration peaks after initial impact, likely due to recoils within the skull-brain assembly. Depending on helmet shape and impact angle, the fraction of the peak G force on the skull transferred to the brain changed. This could indicate energy was being dissipated over a longer time by rotational or tangential forces as opposed to axial recoil which would be a significant factor to consider in the design of future helmets.

Summary Statement

This project focused on using drop tests to understand the relationship between bicycle helmet design and helmet performance as measured by the peak G force transferred to a skull/brain model as the angle of impact was increased.

Help Received

I would like to thank my parents for their financial support, for their safety oversight, and for their assistance in running the video camera while I was in the scene conducting tests. I would also like to thank my adult supervisor, Mr. Jonathan Brix, for his encouragement.

Name(s)

Ethan Wong

Project Number

S0326

Project Title

Effects of Spanwise Lift Distribution on Induced Drag of a Glider Wing

Abstract

Objectives

This project was undertaken the compare the efficiencies of wings with different spanwise lift distributions, including rectangular (the simplest to manufacture), elliptical (the industry standard), bell-shaped (theoretically superior, but has remained obscure since it was proposed in 1933), and triangular (my own design that is a compromise between favorable aerodynamic features and ease of manufacture).

Methods

The formulas that describe the four lift distribution curves tested (rectangular, triangular, elliptical, and bell-shaped) were mathematically derived. Using these formulas, the amount of lift needed at different points along the wings was calculated. Using published wind tunnel data, the degree of wing twist required at these points to generate the desired amount of lift was determined. The wings were then constructed using foam blocks or plastic-covered balsa wood. To test the efficiency of the four wings with different lift distributions, they were attached to the same fuselage to create four different gliders. The gliders were then tested under nearly identical conditions, and the distances they flew were taken to reflect their efficiencies.

Results

An elliptical lift distribution resulted in significantly longer flight distances (mean +/- standard deviation: 93.6 +/- 4.45ft) than the triangular (83.7 +/- 3.57ft) or rectangular lift distributions (77.5 +/- 5.22ft) ($P<0.001$). The bell-shaped lift distribution performed similarly to the elliptical, averaging 94.55 +/- 2.98ft ($P=0.45$).

Conclusions

A wing with an elliptical lift distribution is more efficient than those with rectangular or triangular lift distributions. This is expected since the elliptical lift distribution was a major improvement over previous wing designs. By decreasing wingtip vortices, it greatly reduced lift-induced drag. Unexpectedly, the bell-shaped lift distribution, which theoretically further reduces lift-induced drag, performed no better than the elliptical distribution. Because the difference in efficiency between the bell-shaped and elliptical lift distributions is expected to be small, it may not be detectable by experimental system used in this project. However, in aviation even minute differences in efficiency offers tremendous savings in fuel costs and greenhouse gas emission over the lifetime of the aircraft. Therefore, the bell-shaped lift distribution deserves further exploration after addressing some of the shortcomings of this project that are inevitable given the resources available to me at this time.

Summary Statement

A wing with an elliptical lift distribution is superior to those with rectangular or triangular distributions, but the theoretical superiority of the bell-shaped distribution over the elliptical distribution could not be confirmed.

Help Received

This project was performed independently by me at home.