Senior Design Projects, Summer 2019

Design and Fabrication of a Test-Rig for Spinning Structures and Devices

Professor Cooley seeks an engineering team to help design and fabricate a test-rig for rotating structures. The test rig will be used to experimentally measure the vibration of structures and devices that rotate. For example, the test-rig will be used to experimentally analyze small-scale piezoelectric energy harvesting devices that attach to and harvest energy from rotating systems.

A schematic of the proposed test-rig is shown below. (i) is an electrodynamic vibration shaker that provides input vibration amplitude and frequency to the slip table (ii) The frame (iii) supports the shaker and table. (Components (i)-(iii) are highly engineered components that will be purchased.) The test-rig (within the dotted (red) box) sits on top of, and fastens to, the vibration table. The electric motor (iv) is connected to the drive shaft (vi) by a flexible coupling (v) that compensates for any misalignments or vibration in the motor. This system drives a disk (viii) at a specified rotation speed. Prototype vibration energy harvesting devices (ix) are attached to the disk. Instrumentation on the rotating vibration energy harvesters will be connected to a data acquisition computer using a slip ring device (x). Computer controllers (not shown) will drive the electric motor and vibration shaker.

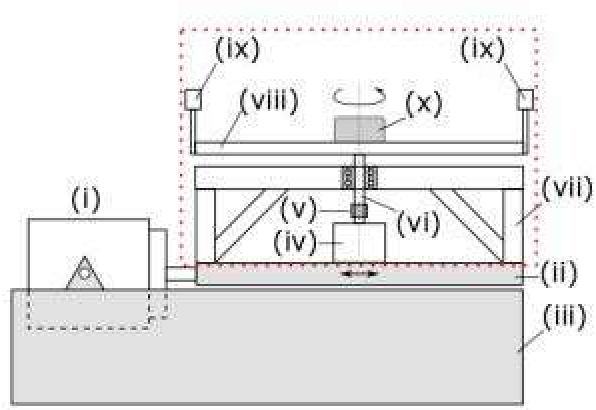

Figure: Schematic of the proposed test-rig.

Desired test-rig specifications:

- Maximum rotation speed of 6,000 rpm (acceptable maximum 3,000 rpm)
- Steady state speed fluctuations below 5%
- Fast spin-up times
- Maximum size of test-rig is 12 inches by 12 inches (to fit on a vibration slip table)
- Maximum weight of 11 pounds (payload limit of vibration slip table)
- Low overturning moment generated at high frequencies

DriveMeSafe, *driving with good intentions*

Continued development of an automotive phone docking station. The DMS docking station disables most phone apps and provides encouraging feedback to inexperienced drivers. The focus target of the product is parents of teen drivers.

Development began in the Winter 2019 semester, with two prototypes produced that had varying degrees of success meeting the specifications. The goal of the summer is to produce a marketable prototype/demo, concentrating on the following improvements to what was developed last semester:

Hardware: Create a smaller version of a prototype with refinement in the area of mechanical push button activation and sensory opening and closing of the phone holder clamping system.

There needs to be a sound audio cue for the driver that matches with the visual display led. The visual display should show three colors: red (dock phone immediately), yellow (caution be on alert), green (safely docked).

Software: Mobile application developer to update software interface to have an administrator account and a user account. Administrators should have complete control over the user mobile device usage behind the wheel. Administrators can create policies that eliminate access to texts, email, handheld calls, games and any other inappropriate app usage while allowing mission-critical apps through the system. Software should be able to detect where phones are in the vehicle and enforce the protection policy only in the driver-seat zone or throughout the entire vehicle. Option to limit the incoming calls an in case of emergencies while allowing apps like navigation to still be functional.

Non-disclosure and assignment agreements are required before students can commence work on this project.

Robot-facilitated group whole body exercise intervention for older adults

The perception humans have of robots is different from the one they have of humans or other alive beings. This project focuses on a socially assistive robot interacting with groups of older adults. A scientifically proven exercise that has been shown to be beneficial for older adults is Tai Chi. Health care professionals often use Tai Chi as one of the means to improve on older adults' well-being yet convincing them to participate in such interventions is often challenging. Using social robots may make the job of health care professionals easier. The operator wouldn't be seen or heard by the people it works with, but people will observe a cute-looking robot, to whom they also relate with less social anxiety.

The proposed deliverable of this project is a robot facilitated group whole body exercise intervention for older adults. The robot that will be used is the Pepper Humanoid Robot from Softbank Robotics. Pepper does not have legs, therefore it will play role of facilitator to a Tai Chi session with a limited to upper body Tai Chi motions. The whole Tai Chi session would be performed on a projector and would be controlled by the Robot Operator. Pepper Robot on itself would be controlled using Virtual Reality by the robot operator. The control for the system will happen mainly from the robot operator thorough a VR system, converting the VR controllers' position and orientation to robot's hands position and orientation. The intervention that will be running on projector should also be designed to allow simple communication interface for robot operator from VR system, such as starting and stopping the intervention, skipping through certain parts, or jumping to desired parts.

The project is based around working with group of adults and may require addition of certain sensors outside of the robot. Pepper is shorter than an adult, therefore it cannot observe whole group very well. To solve that problem, portable and wireless sensors such as cameras, depth cameras, and audio recorders may be implemented. The sensory input will be used to filter out abnormal behaviors (for example falling) and will alert the operator.

Technical objectives:

1. System that would translate upper body movements from VR system to robot's upper body movements.
2. Create some engaging behaviors and have a scripted version of the Tai Chi on the robot.

3. Application (preferably web based) that will run Tai Chi intervention on screen/projector, and would be controllable from VR system.
4. Interface within VR system that would allow to move robot around, make parametric adjustments to the system, and control the application running Tai Chi intervention.
5. Wireless portable stands that keep track of their locations relatively to each other, record image, depth, and audio data, and communicate everything to computer.

Proposed Guides: Dr. Louie, Assistant Professor, Department of Electrical and Computer Engineering.

LapLok

LapLok is a portable security device that allows a laptop computer (or purse or briefcase) to be temporarily yet securely attached to a public table or counter, allowing the user to step away from the table briefly, for example to use the restroom or place an order, without taking all of her/his belongings. An artist's conception of the LapLok is shown. The basic mechanical design of the LapLok is nearing completion.

The tasks required from this semester involve the development of 3 versions of the LapLok:

Model 1 – Basic mechanical LapLok
1. Do project timing plan w/ completion 2 weeks before end of semester & weekly milestones
2. Find vendor, interface for low cost & functional, user changeable lock w/ 1,000 combinations
3. Cost target – $1 or less at 5,000 pieces
4. Finite Element Analysis
5. Pulling force to remove from table - 100 pounds
6. Can be dropped from five feet & still work
7. Testing & report that shows product meets specifications
8. Must be user friendly, simple, fast & easy to operate, compact & excellent appearance
9. 2 functional & working prototypes that meet specifications & look like production
10. Select type, thickness & durometer of rubber
11. Costed bill of material
12. Vendors for all parts
13. Drawings w/ dimensions & tolerances for all parts designed for low cost tooling
14. Steps & procedure & estimated timing for all steps for low cost assembly

15. Find manufacturer in Michigan that meet cost target FOB factory of $4 w/ excellent quality

Model 2 - Same basic appearance & function as Model 1 but add piezo & sensor

1. Small, compact, low cost & excellent appearance
2. Need design for consumer marketplace w/ excellent styling
3. 2, functional, working, good looking prototypes that look, sound & work like production
4. Finite Element Analysis
5. Sensor detects someone has lifted computer up ~ .1”
6. Same loudness as smoke detector
7. Thief not able to easily stop piezo from sounding (assumes he does not know code)
8. Activated when user puts LapLok in Lock mode & deactivated when user unlocks LapLok
9. Small, low cost, battery (s) that can be easily replaced from bottom so thief could not remove it when LapLok is attached to table
10. Power - sounds up to 5 times in two years for 1 minute each & have at least 2 years of shelf life & as small & low cost as possible
11. Low battery indicator – small, red LED flashes w/ low battery 10 times for .2 second duration each 3 seconds after lock is set but has enough battery life for at least one sounding after this within 6 months
12. Operating temperature from 32 to 100 degrees F

Model 3 - Model 1 & 2 plus signal to cell phone that says someone has lifted computer

1. Signal to cell phone w/ low battery indicator
2. Work w/ all cell phones & range from cell phone to LapLok 300’
3. Software & app for cell phones
4. Includes app design, input, output, function, appearance, user interface, etc.

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Scrolling Billboard

A new concept for a 14’x48’ billboard that provides the ability to display several advertisements, like a LED billboard without the extreme cost (1/3 cost and 1/6 power) and maintenance. Much of the mechanical design is done but there is still much to do. Verification of the system is necessary, as is the development of several important components.

The tasks required from this semester's effort include:

1. Complete and/or review all parts & assemblies for the following:
    a. Write software to Add, Move & Remove Signs & Curtains (have PowerPoint w/ steps)
    b. Needed for both Signs & Curtains
    c. Finite Element Analysis for all key components w/ documentation to support findings
    d. Make small, 2' x 2' model of Acrylic front. We have Acrylic & design.
    e. Tolerances and tolerance stack-ups for assemblies
    f. Review expansion/contraction
    g. Find way to reduce present design by $1,000
    h. Appearance & Installation
    i. Freight & handling
    j. Mounting to an existing billboard pole
    k. Mechanics, camera, electronics, software, etc.
    l. Work w/ Dr. KaC Cheok's group on controls
    m. Documentation of life, strength, etc. to satisfy a potential $500k investor
2. Study various mounting poles for
    a. Mounting & what is available & various attachment configurations
    b. VEE billboard mounting & how to handle this
    c. Back-to-back billboards & how to handle this
3. Life analysis
    a. Do analysis w/ potential life of 10 - 20 years & document analysis. Must consider temperature from – 30 to 120 degrees F, wind, rain, snow, ice, hail, etc.
    b. Three requirements
        i. Must scroll in wind up to 40 MPH
        ii. No parts can fly off at 120 MPH
        iii. Must still work after winds to up 120 MPH come back down to 40 MPH or less.
4. Manufacturing
    a. Do costed Bill of Material
    b. Do analysis of time to make parts & do assembly
    c. Find components that meet cost targets
    d. Help find <u>Michigan manufacturer</u> to build it w/ cost target of $30,000 FOB factory
5. Improvements
    a. Flat tube support system
        i. Do in-depth analysis of Dr. Latcha's innovative design to keep tubes level. It reduces billboard cost by ~ $800.
        ii. Build a prototype, test it & show w/ 3D animations and/or video.
        iii. Need in-depth Finite Element Analysis over time and/or whatever type of analysis is required & write a report supporting findings. FIS study?
    b. LEDs inside billboard w/ translucent Sign & Curtain material so billboard looks almost exactly like an LED billboard
        i. Design LED & lights required & show w/ 3D animations or small prototype
    c. Billboard w/ no Acrylic front to reduce cost. Design & analyze.
    d. Ways to improve design or lower cost
        i. Smaller motors and/or system w/ clutch or other stored energy technique to make motors smaller
        ii. Look at a Pareto chart of cost & work on highest cost items first

iii. Find sources, techniques or parts that meet quality standards to reduce cost

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Auto-Injector (OU School of Nursing)

We would like to see a device developed that would allow nurses to prepare a syringe full of medication, load this medication, and administer it in a manner similar to an Epi-pen. Currently, there is no such device on the market that allows for loading on demand. All auto-injectors come with a predetermined medication and dose. The ability to use auto-injector delivery would be a desirable delivery method in environments like ER and psychiatric settings, where nurses and staff may need to give medications to combative patients, and the risk for needle stick injury is high.

The goal of this prototype would be to develop a device that would have a single-use tip (at least the actual needle and part that would sit against the patient's skin), and would handle an intramuscular injection, which would require a high level of sharp stability, a large gauge needle and the ability to hold a 3ml syringe such as those already in use at the hospital. The ability to use as many existing supplies as possible is desirable. Additionally, transparency in the body of the device would be highly desirable as all medications must be labeled in the hospital. The major aim of this device would be to essentially provide the ability to take a syringe of medication and deliver it through an auto-injector as needed, allowing a nurse to draw up the exact dose needed for the patient and administer it safely. Major considerations include infection control, cost and safety.

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Ception e-Stim

Primary use case: targeted electric stimulation (e-stim) of affected muscles to achieve rehabilitative functionality to accomplish activities of daily living (ADL) such as wheelchair mobility or transfer movements.

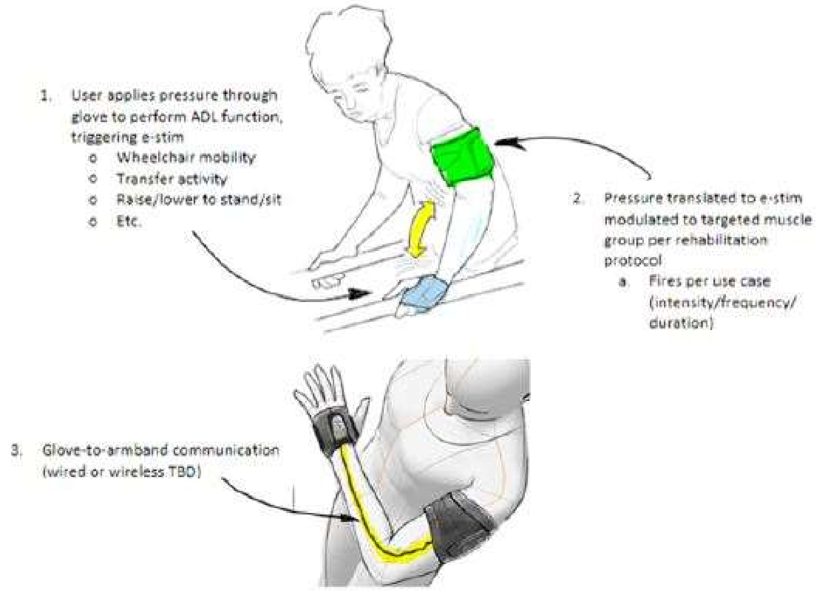
Core device/system:

- Glove w/imbedded pressure sensors to trigger e-stim appropriate for desired force/effort, etc.
    - Battery powered
    - Includes e-stim intensity adjustment/control, on-off power switch, etc.
- Arm band w/imbedded sensors & e-stim pads to translate glove force inputs to e-stim outputs on targeted muscles, plus master control module.
- Wired/wireless (Bluetooth) communication between glove & armband control module

Glove w/pressure sensors:

- "Bike glove" w/imbedded OTS flat sensor pads
- Direct wired to arm band

- Simple knob or rocker button for intensity control
- On/off switch
- Battery power
- Next Gen: Bluetooth connectivity (to arm band)



Arm band w/e-stim pads:

- Neoprene workout band" (eg. cell phone holder)
- Imbedded FES nodes, repositionable per e-stim requirements
- Position sensor
- Battery power
- On/off switch
- Add intensity/settings control
- Next Gen: Bluetooth connectivity (to glove)

Senior Design Lab Project approach:

1. Build working prototype of Ception system
2. Use OTS components as needed
3. Refer to OTS in-market component specifications
4. Investigate optional Bluetooth communication (glove to arm band)

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TekLux LED lighting project - ROCO Supply, Inc.

The goal of this project is to develop a work task light that will evenly light an area of 2 meters squared from 1-meter height. The surface lux should be 1500 lux or higher at all points on the surface. A group developed a prototype of the light last semester in senior design but ran out of time to accomplish all of the specifications, namely that of evenly lighting the surface.

Tasks to be accomplished, issues to be explored:

- by focusing the light through the use of different lens we can greatly increase the lux measured on the target surface.
- the problem is focusing the light without creating a spot light effect (hot spots)
- each led or possibly a group of LEDs within the array will be lenses to direct the light to the target surface in order to create uniform light.
- it could become an issue with the heat sink NOT having enough surface area where the led strip is placed to accommodate the lens (off the shelf types).
- the physical spacing of the LEDs on the strip may have to be changed.

We are able to produce enough light at a low current draw using the existing heat sink design. Using the higher efficacy LEDs from Nichia (or others) will increase the lumen (and lux). I have sample Nichia LEDs that came in too late for last semester.

Light can be directed through lensing to project an even pattern. How we accomplish this is the project in a nutshell.

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Design of a Reverse Electrodialysis (RED) Cell for Generating Electricity from Salt

(Dr. Maisonneuve)

Reverse electrodialysis (RED) involves the mixing of ions to generate electricity. The RED cell consists of an alternating sequence of cation-exchange membranes (CEM) and anion-exchange membranes (AEM) stacked between a pair of electrodes, as shown in Fig. 1. When supplied with alternating streams of concentrated and diluted solutions, the result is the establishment of an electric potential due to the diffusion of ions across the respective permeable layer. Typically, this process has been studied for application to estuaries where large salt water gradients exist. However, this project investigates the use of common fertilizers, with the goal of demonstrating for the first time, RED electricity generation from fertilizer. Such a system could be applied to hydroponic farms where fertilizer is diluted prior to irrigating plants (very common practice). If converted to electricity, this energy could be used to supply key farm loads such as critical pumps, lights, sensors, etc.

To accomplish this goal, students should design and build a custom RED cell resembling the one shown in Figure 2. Materials, cell geometry, and scale should be carefully designed for compatibility with the existing laboratory bench, for performance, and in line with the specified budget. The cell should have channels between AEM and CEM membranes that will specifically allow only one solution to flow into and out of each cavity. The cell should also have two electrodes, an anode and cathode, imbedded into each respective endplate. The electrodes should each attach to an external load across which potential and current can be measured. Once built, students should show successful operation by demonstrating voltage and current output under variable resistive loads and given various fertilizer inputs and circulation rates.

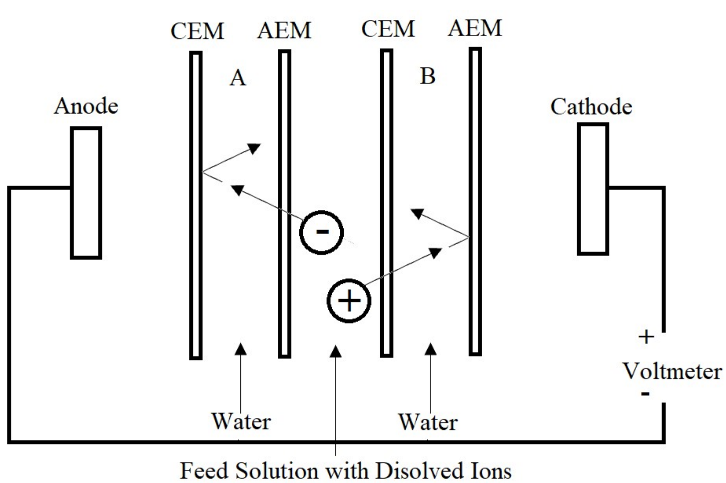

Figure 1: Reverse electrodialysis (RED) process where A represents the negatively charged solution and B represents the positively charged solution [1].

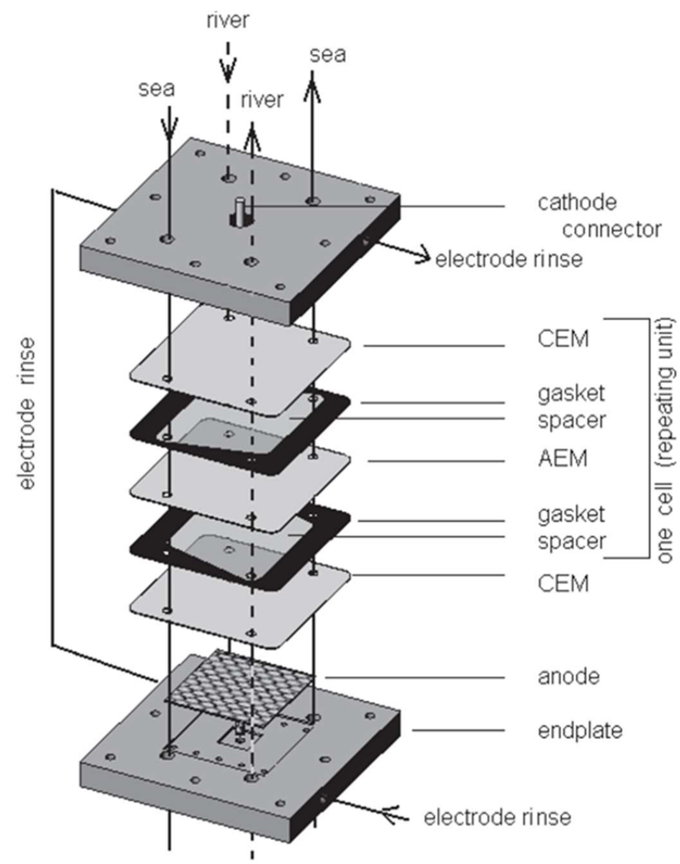

Figure 2: Anatomy of a reverse electrodialysis (RED) cell [2].

References:

[1] J. W. Post, "Blue Energy: electricity production from salinity gradients by reverse electrolysis," Thesis, Wageningen University, Wageningen, NL (2009)

[2] J. Veerman, M. Saakes, S.J. Metz and G.J. Harmsen, "Reverse electrodialysis: performance of a laboratory device with 50 cells on the mixing of sea and river water," Journal of Membrane Science 327 (2009) 136-144

Harvesting the Motion of Water Waves – Linear Wave Generator

In our work with Wave Water Works, one difficulty that we have constantly had to deal with is the fact that the low-power water waves are also low speed, typically 10-20 cycles per minute. This makes it very difficult to generate electricity with conventional generators. Mechanically speeding up the motion is counterproductive and very expensive in terms of the available power in the waves.

Beginning last semester, we are exploring the idea of generating 100W of electricity using an array of small floats, each containing a linear generator. The goal was to design, construct, test and demonstrate an effective yet inexpensive linear generator, tuned to efficiently generate power at 10-12 cycles/min, and develop a system to connect several floats in order to continuously charge a 12 V battery.

We were successful in several aspects of this project yet more work remains. Namely

- Develop a mechanical fixture to efficiently wind generator coils of various diameters and thicknesses, of magnet wire of various diameters, and to a target number of windings
- Develop a strategy to manage the power developed from an array of small floats, with the purpose of generating 50-100 W of electrical power in order to charge a 12V battery
- Using common materials, build and demonstrate a prototype linear generator tuned to typical wave frequency that can be commercially produced.