About the Department of Mechanical Engineering at Dalhousie University

From the MERC 2015 organizing committee

This year the Department of Mechanical Engineering at Dalhousie University is hosting their eighth annual research conference. Thirty one graduate students from the Department of Mechanical Engineering will present on a variety of topics including: advanced control systems, advanced manufacturing, micro-electro-mechanical systems (MEMS), energy management, and thermal treatments for biomass. The conference is designed to provide graduate students with a platform from which to present their research to an audience from academia and industry.

The Department of Mechanical Engineering offers a strong program at the undergraduate and post-graduate levels aimed at meeting the needs of Canadian industry. Active research programs within the Department focus on experimental and applied numerical and computational investigations on a wide range of topics. The Department has approximately fifty post-graduate students (MEng, MASc, and PhD) and 240 undergraduate students.

Faculty members within the thermo-fluids group are active in the field of energy utilization including solar energy, fluidized bed combustion, and computational fluid dynamics. This research includes energy management in the residential, commercial, and industrial sectors; experimental and numerical heat transfer; and alternative energy solutions. Extensive experimental facilities have been developed for all of these research areas.

Within the solid mechanics group, the research programs are focused on a wide range of applications including powder metallurgy manufacturing, grinding manufacturing processes, smart materials, applied control systems, aquatic and ground-based vehicles, and MEMS. Advanced numerical investigations are undertaken using finite element methods, multi-physics approaches, and analytical methods. Also, considerable focus is placed on experimental testing, development, and innovation.
Committee Members

Andrew McDonald  
Chair

Emir Okyayli  
Deputy-Chair

Dane George  
Communications Clerk

Andrea Felling  
Consultant - Past Chair

Dr. Marek Kujath  
Faculty Advisor

Dr. Jimmy Chuang  
Faculty Advisor

A Special Thanks to:

Selina Cajolais  
Graduate Secretary

Peter Jones  
Department Engineer

Dr. Ted Hubbard  
Professor of Mechanical Engineering
## Schedule of Events

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8:30-8:45

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8:45-9:00

### Keynote Address
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### Group Photo
10:00-10:10

### Morning Break
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### Health Break
2:00-2:30

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### Closing
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Posters

Ahmed Tousif  
*Thermal behaviour analysis of tablet computers*

Clark Calnan  
*System Uncertainty and Robust Control*

Ali Cherom Kheirabadi  
*Numerical Modeling of Phase Change and ON/OFF Temperature Control using COMSOL Multiphysics in Designing an Automated Thermal Cycler*
Keynote Speaker:

Jim Hanlon
Co-Founder & Chief Technology Officer, Twist Bioscience.

Jim is a 35-year veteran of the tech industry, having worked in design, marketing and management for companies in Canada and New England. His career has spanned the aerospace and defence sectors as well as the marine environmental monitoring and satellite telemetry fields.

Over the years, Jim has worked in senior management positions with several large publicly traded companies but has also been an owner of two separate tech companies that have successfully grown and been purchased by multinationals. In May of 2012, Jim assumed the role of CEO of the Institute for Ocean Research Enterprise, a not-for-profit company established to foster collaborative ocean research among universities, government labs and private companies.

Jim holds a Bachelor of Electrical Engineering degree from Dalhousie University and an MBA in marketing from Saint Mary’s University in Halifax and he is a registered professional engineer in Nova Scotia.

Jim is married with 3 adult children and enjoys sailing.
Sponsors:

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DALHOUSIE UNIVERSITY mechanical engineering
Abstracts
Manufacturing of Hard Chrome Plated Parts
Presentation

Abdullah Almotairi, Andrew Warkentin and Zoheir Farhat

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1360 Barrington Street, Halifax, NS, Canada B3H 4R2
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Keywords: Hard chrome plating, grinding, coating characterization

Hard chrome plating is utilized extensively in industry because it can provide parts with a variety of properties including high hardness, wear and corrosion resistance and low friction coefficient. Chrome is electroplated onto an object when a negative charge is connected to the object and a positive charge is connected to an electrolyte solution that contains chromic acid. When dipping the object into the solution, chromic ions carry positive charge and are deposited on the object. Plated parts are usually ground to achieve final tolerances. However, high hardness and plating thickness make grinding of hard chrome challenging. Atlantic Hardchrome Limited, a local company specialized in hard chrome plating, has asked us to improve the process of producing hard chrome plated components since it is a major process in their plant. Therefore, the objective is to find methods of reducing the cost of manufacturing chrome plating. This research consists of two parts. The first is to optimize grinding process. Grinding experiments will be conducted to study the effect of key parameters, such as feed, cross feed and depth of cut. The second part is material testing where the coating is characterized before and after grinding to evaluate the impact of grinding parameters on coating integrity. Samples were plated on 416 stainless steel for different time so various plating thickness can be obtained. Scratch test will be employed to test coating adhesion to substrate as a function of plating thickness. Increasing applied load will be used in scratch tests to find critical load at which failure occurs. Nano-indentation and wear reciprocating tests will be used to assess mechanical and tribological properties of the coatings, respectively. Scanning electron microscope (SEM) examination will be conducted to evaluate the coating integrity during wear and scratch experiments and find possible operative wear mechanisms. Recommendations will be made for process improvement to Atlantic Hardchrome.
Wild blueberries are an important horticultural commodity native to Eastern Canada, contributing millions of dollars to provincial and federal economy annually. In the last two decades, improved management practices using selective herbicides, fertilizers and pesticides have resulted in changed crop conditions and significant increases in fruit yield. The wild blueberry industry is facing increased harvesting losses because of these changes in crop conditions. This study was designed to characterize and quantify the spatial pattern of variability in crop characteristics, fruit yield and slope in relation to fruit losses during mechanical harvesting. Four wild blueberry fields were selected in the Nova Scotia and New Brunswick provinces of Canada. Factorial experiments were constructed and eighty one yield plots (0.91 × 3 m) were selected randomly in each field. The total fruit yield, un-harvested berries on the plants, berries on the ground, and berries through the blower, were collected from each plot within the selected fields. The pre-harvest fruit losses were collected from each plot prior to harvest. The slope, plant height, and fruit zone were also recorded manually from each plot to examine their impact on fruit losses. The field boundaries, bare spots, weeds and yield plots were mapped with a real-time kinematics global positioning system (RTK-GPS). The coefficient of variation (CV) of the fruit yield, fruit losses, slope and crop parameters suggested moderate to highly variability (CV>15%) within selected fields. Results of correlation analysis indicated that the fruit losses were generally higher in high yielding areas and vice versa. Results reported that the fruit yield, slope, losses and crop characteristics had a large spatial variation with the range of influence ranging from 20 to 50 m within selected fields. Kriged maps of these parameters also showed substantial variation within selected fields emphasizing the need to operate the harvester in relation to variability for effective berry recovery. Regression analysis in conjunction with zonal statistics showed that the fruit losses increased with the steepness of slope within selected fields. Overall, the results of classical statistics, correlation analysis and geographical information system (GIS) mapping revealed that the crop parameters, fruit yield, slope and fruit losses were highly variable within selected fields. This study will help us to identify the factors responsible for fruit losses and suggest optimal harvesting scenarios based on spatial variations during harvesting.
Multi-agent systems are composed of several intelligent agents which are capable of interacting with each other through communication channels. These agents are mainly computer controlled systems which are capable of performing any autonomous action in order to achieve its assigned tasks or objectives. Most of these tasks are required to be performed in teams and formations wherein all agents have to achieve a consensus among them. In other words, multi-agent systems are distributed computing systems.

Information consensus has become a hot research topic in the coordination control of multi-agent systems, more and more researchers are getting interested in it due to its wide engineering applications. A fundamental and significant problem for information consensus is how to design a proper control law that enables the states of all agents can converge to a value which is constant or changeable in the presence of limited and unreliable information communication topologies.

In this presentation, the problem of consensus convergence in multi-agent systems with constant delays and packet loss is investigated. Derivation of error dynamics for consensus of multi-agent system considering the constraints in the system is explained. Stability analysis of the system is carried out using the theory of Lyapunov function, a sufficient condition expressed in LMI is given to guarantee all agents achieving consensus asymptotically under communication delays if the network topology is connected. Particularly, several feasible LMIs are proposed to determine the control gain and the maximal allowable time-delay. There are many LMI solvers available in MATLAB LMI toolbox which help in developing and solving these inequalities as per requirements to get a feasible solution of control gain. Results based on this proposed LMI will be discussed proving the effects of constraints on multi-agent agent system for achieving consensus among their states. Experimental studies on real time mobile robots will be carried out using Pioneer 3-DX in the Advance Control and Mechantronics Lab as a part of future work.
Torrefaction is a heat treatment of biomass in inert atmosphere with temperature range of 200-300 degree C. This leads to improvement in handling properties with enhanced bulk density, energy density, grindability and hydrophobicity. Much work has been done to study the effect of different operating parameters (temperature, residence time, size, presence of oxygen) on product yield for various kind of biomass but there is lack of an index that quantify the degree of torrefaction which relates to effect of biomass type and operating parameters on the quality of torrefaction. For example, when we specify the grade or quality of coffee, we use the term like dark roast, mild, French. All these gradings are based on the roasting temperature. Some people use terms like mild torrefaction and severe torrefaction, but there is no quantitative parameter to express the degree of torrefaction. This parameter should relate different attributes of torrified products on a common platform to express it in a quantative manner.

The present study will collect the information on the experimental data from different sources and develop an index. Also those information would be used to develop a more comprehensive kinetic model taking into account the effect of temperature, particle size and the results will be compared with the existing kinetic models.
Numerical Modeling of Phase Change and ON/OFF Temperature Control using COMSOL Multiphysics in Designing an Automated Thermal Cycler

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Keywords: phase change heat transfer, temperature control system, COMSOL Multiphysics

Phase change materials (PCM) are capable of storing and releasing large amounts of thermal energy when transitioning between solid and liquid phases, a characteristic that has major implications in thermal energy storage systems; this is due to the large latent heat of fusion required for a complete phase transition. When subject to long term use however, questions are raised regarding the thermal performance of PCMs after a significant number of phase transition cycles have occurred. An automated thermal cycling device would allow for frequent, long-term phase transition cycling of PCMs for experimental analysis.

In this context, a thermal cycler is a device that autonomously melts and solidifies PCM samples at a specified temperature and frequency, for any given number of cycles. Such a system was designed and constructed at the Laboratory of Applied Multiphase Thermal Engineering (LAMTE). System heating was achieved through AC powered cartridge heaters, while system cooling was achieved through DC powered thermoelectric cooling assemblies; each cooling assembly consists of a thermoelectric module, a heat sink, and a cooling fan. The system temperature was regulated by a digital ON/OFF control system (Arduino Mega2560) that triggered the heating and cooling systems accordingly as per user-defined parameters.

The initial desired cycling frequency was about 500 cycles per week (20 min/cycle) for eight PCM samples with melting temperatures ranging from 290 to 350 K. In order to ensure these requirements, COMSOL Multiphysics was used to numerically predict the system performance, which included the melting and solidification of PCM samples, in response to the ON/OFF temperature control system. This study presents the numerical techniques used to simulate the thermal cycler performance as well as a comparison between these predictions and actual system performance after construction.
Value Added Utilization of CFB Ash in Various Applications
Presentation

Anantkumar Patel and Prabir Basu

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Keywords: Utilization of CFB fly ash and Bottom Ash, Bricks, CO2 Capture, Absorbent

Circulating Fluidized Bed (CFB) power plants have been gaining popularity globally due to its clean operation and higher efficiency characteristics. Coal combustion wastes (fly ash, bottom ash, slag, flue gas desulphurization) from CFB boiler are harmful to environment and ecosystem. Considerable research has been done in utilization of these wastes. However, high amount of sulphate contents in the ash due to sulphur capture in the furnace restricts its usages in many commercial applications. At present CFB combustion wastes are not being utilized and they are dumped in a landfill site. The aim of this research is to study the suitability of fly ash and bottom ash collected from Point Aconi power plant (NS, Canada) and compare the results with pulverised coal fired ash in various applications such as manufacturing of building and construction materials, sequestration of carbon dioxide from flue gases, uses as an absorbent to remove organic and inorganic elements from waste water and effluents.
Development of a Portable Video Extensometer System
For Compressive Material Testing
Presentation
Andrea Felling and Darrel Doman
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Keywords: Computer Vision, Material Properties, Finite Element Modeling, Upsetting Test

A critical step in the development of any new material is the characterization of its mechanical properties such as Young’s Modulus and Poisson’s Ratio. These critical properties are determined experimentally by subjecting test samples to known loading curves, and measuring the resulting strain. Typically these strain measurements are taken using either a strain gauge or an extensometer in direct contact with the test sample. While these methods work well in many cases, they do not work nearly as well on extremely compliant or brittle materials. For cases where traditional methods are impractical, it is possible to measure strain without any physical contact, using a camera to measure the deformation in the test sample. These systems are known commercially as video extensometers.

This presentation outlines the design of one such video extensometer system, designed for use in compressive testing of powder metallurgy samples. The system is tested against calibration samples under zero-load conditions to assess the accuracy, resolution and repeatability of the system’s measurements.

The system is also tested using finite element methods. Samples of aluminum are subjected to compressive loads, and the stress-strain curves measured from the test are used to generate element model of the test samples. The real-world results are compared to the model results to show that the stress-strain properties measured with the system accurately predict material behaviour under compressive loads.
Improvement of 3D Scanner for Grinding Wheel Characterization

Andrew McDonald, Robert Bauer and Andrew Warkentin

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Keywords: Grinding, Surface Topology, FASCAT, Characterization, Image Analysis

Grinding is an abrasive manufacturing process in which a rotating wheel is brought into contact with the workpiece. The grinding wheel is comprised of abrasive grains which act as cutting tools as well as bonding material. Studies have shown that the workpiece surface topology, heat transfer and power consumption are all linked to the surface condition of the grinding wheel.

The grinding research group at Dalhousie University has developed a Fully Automated Surface Condition Analysis Tool (FASCAT). FASCAT uses a combination of a white light chromatic sensor, linear actuator and friction drive to obtain depth measurements from the wheel surface. The previous generations of FASCAT have not had the reliability or accuracy necessary to confidently use the device; therefore, the purpose of this thesis is to: implement a new control system to increase the reliability and accuracy of FASCAT, incorporate a second rotary encoder to increase the resolution in the x-direction by a factor of 40, and develop a new method for homing the device using a digital camera and a circular target placed on the grinding wheel hub. An image analysis program has been created in LabVIEW to monitor the location of this target and rotate the grinding wheel until the target is in the desired “home” position. By using a circle as the target, the homing program is able to monitor the location of the target with sub-pixel accuracy enabling the grinding wheel to be positioned with only 2µm of error. This homing feature will allow for the wheel to be removed from the device and placed in the same position after successive grinding tests.

The newly modified FASCAT must first be fully characterized in order to determine optimum scanning settings. Once a detailed characterization of the device is complete, it will be used to monitor the wear of the grinding wheel throughout the grinding process.
Nowadays, many countries are encouraging the use of photovoltaic (PV) energy to support the electrical grid network because it is one of the most attractive technologies for solar energy application. The cost of PV power has declined dramatically in the last five to six year, and it appears that the cost of electricity from PV modules will be competitive with other solar thermal applications and conventional electrical power. Although currently the PV power is more expensive than solar thermal systems, PV water heating systems offer the possibility of being less expensive than solar thermal systems in the near future. Therefore, some consideration for the design of this system will be made to evaluate the stratification in storage tanks using a PV powered heating system. The objective of this research is an experimental investigation to enhance stratification in solar domestic hot water (SDHW) tanks using a PV powered heating system. Many researchers have found that thermal stratification has the effect of decreasing the periods of operation of the auxiliary energy supply, so that the energy storage efficiency for the whole system may be increased. Researchers have found that thermal stratified tanks provide a better quality of energy to the load and can produce more heat than fully mixed tanks.

There are a number of factors that affect the degree of stratification inside a storage tank. How closely a practical tank can approach the ideal tank is still an open question and the proper design to enhance stratification in storage tanks still needs further work of both experimental, theoretical investigation and developing devices that enhance the stratification. However, the proper design to enhance the stratification inside a side-arm storage tank using PV power heating is not yet determined.

Thermal energy storage is one of the main components in a SDHW system. Designing and constructing an affective thermal storage tank for a SDHW system is essential for meeting the heating demands when the supply and the exhaust of energy cannot be kept in balance. For this reason, thermal energy storage has been an important area of research for enhancing the performance of SDHW systems. This research will use a PV SDHW tank with a side-arm heater design as opposed to the traditional electric immersion heaters in order to increase the thermal stratification of the water inside the tank, which will create a higher thermal quality in the tank.
Thermal Modeling of Tablets: Temperature Management Using PCMs

Presentation

Benjamin Sponagle and Dominic Groulx

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Keywords: Passive temperature control of electronic devices, Latent heat thermal storage, Phase change materials, numerical study

One of the dominant trends in the portable electronics market has been towards devices with more processing power and smaller form factors. If this trend is going to continue, without a fundamental shift in computing technology, cooling will become an obstacle. As processing power increases so does heat dissipation and as form factors decrease it becomes increasingly more challenging to dissipate this heat efficiently. In stationary computing applications active cooling is employed to facilitate the cooling of electronics (ie. fan and heat sink assemblies or liquid cooling). However, it is challenging to extrapolate modern active cooling technologies into portable electronics packages. The major limitations being first and foremost space, but also noise concerns. Instead of focusing on active cooling this work will focus on the improvement of passive cooling, through the use of phase change materials (PCMs) and careful heat sink/heat spreader design. With the goal of both managing heat more effectively in modern electronics, but also with an eye on future electronics applications. This work will consist of three major phases. Firstly, building of a representative numerical test case for a portable electronics platform with a focus on thermal modeling. This will involve assimilating data from several sources (mainly, in house analysis of current generation devices and discussions with our industrial partners) into a numerical model built in a commercial simulation software. This model will focus on realistically modeling the structure, materials, and heat dissipation of a portable electronic device. Challenges will include accurately recreating a representative design given the scale of these devices and determining the transient heat dissipation profile of the device for various use modes (ie. what happens when browsing the internet, streaming data, watching a movie, etc.). Fortunately, the small form factors of these devices will mean that all internal heat transfer will be strongly diffusion dominated which will help simplify the numerical simulation and shorten computation time. Secondly, will be the use of this test case as a numerical laboratory for the implementation of different passive cooling technologies and different combinations of these technologies. With the eventual goal of using the numerical test case as a platform for optimizing a passive cooling technique which consists of an elegantly designed combination of PCM, PCM encapsulation, and heat sink design. The final phase will be to use the numerical results to facilitate and direct our experimental investigations of passive cooling. This will likely include simpler designs at first but the ultimate goal is to implement our passive cooling techniques, perfected in the numerical studies, on a realistic experimental platform.

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A mobile manipulator is a manipulator arm mounted on the mobile platform to offer more flexibilities to reach to the target position in the space. In recent years, research activities in this area have expanded because of the mobility merges with the manipulation. A good amount of research and improvements have been carried out in the field of nonholonomic control of mobile vehicles and motion control of manipulator arms. If the dynamics of the mobile manipulator is known, feedback linearization can be applied to develop a nonlinear control law. The fundamental concept is to numerically remodel a nonlinear system dynamics into a linear system dynamics so that linear control approaches can be applied. In literatures, control methods such as state-feedback, output-feedback, dynamic coupling, model-based, adaptive tracking control, etc. have been applied to the control of mobile manipulators.

One of the objectives of this research work is to construct the systematic modeling of kinematics and dynamics of the mobile manipulator using the Lagrangian dynamics under the holonomic and nonholonomic constraints and then algebraically transform it to a linear one. Using the idea of feedback linearization from the literature, model-based control is presented for the mobile manipulator. It considers the motion control problem of the holonomic constrained nonholonomic mobile manipulator for the desired task. If the system dynamics are available, this control can provide an efficient solution to the motion control problem. System dynamics is modeled in the Simulink MATLAB and appropriate controller is modelled for the specified task. Simulink results confirm that the model-based control method guarantees that the mobile manipulator states converges to the desired given trajectories. Constraint force can also be controlled using the model based control and hence not only the system states converge to the desired trajectory, but also the constraint force converge to its desired force.

Future work will be investigating new robust nonlinear control method for the control of mobile manipulators, in the existence of unknown system parameters, uncertainties and external disturbances. Extensive simulation studies are going to be carried out for verifications.
Design and Test of MEMS Thermal Actuator with Mechanical Amplification Able to Perform Single-Cell Tests underwater

Bruno Barazani, Ted Hubbard

Keywords: MEMS, Thermal actuators, Mechanical amplification, Sub-micron displacements, Cell testing

Micro-electro-mechanical systems or MEMS are microscopic devices used to drive tiny structures or to detect motions on the order of micrometers. MEMS stand out over traditional macro devices due to miniaturization advantages such as higher sensitivity and easy microelectronics integration. Recently, MEMS have been claimed as promising tools for the measurement of living cell mechanical properties. Wide force range and well defined load conditions are some of the reasons for that. MEMS thermal actuators produce sub-micron motion when heated by electrical current going through their structure. They are commonly designed in a ‘V’ shape geometry (chevron) that amplifies their output motion. However, their performance drops considerably in aqueous media. Therefore, the aim of this study is to design and test a thermal actuator with a longer range of motion in water. The study first measures the sub-micron motion of a chevron thermal actuator in air and water and then measures the performance of the new design underwater. The proposed design provides a theoretical motion amplification of about 10 times and consists of two chevron actuators with a mechanical amplifier in between them. Measurements of displacements were performed using an FFT image analysis algorithm with sub-micron precision. Experimental results show a displacement of 1.11 ± 0.01 µm in air and 67 ± 17 nm in water for the chevron at 6 V. Hence, the performance of the chevron actuator in water is about 6% of its performance in air. The new design shows a displacement of 404 nm ± 6 nm at 6 V underwater; therefore, it amplifies the chevron displacement by a factor of approximately 6. The larger motion range of the new actuator leads to a more accurate measurement of cell mechanics and allows a higher cell deformation percentage.
Evaluation of Time and Energy Requirements in the Formation of Lead-acid Batteries

Chris White and Lukas Swan

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Keywords: Lead-acid Batteries, Formation, Energy

Lead-acid batteries are a common energy storage technology used in such applications as back-up power system, automotives, and renewable energy storage. ‘Formation’ is the name given to one of the final steps in the battery manufacturing process, in which the batteries are electrochemically activated by a lengthy electrical charge that can last several days. The charge can be applied using one of four different techniques, all of which are employed by Surrette Battery Company, a lead-acid battery manufacturer located in Springhill, Nova Scotia. Since the variations in time requirements, energy requirements, and product quality associated with the four formation techniques at Surrette have not been researched, the company has partnered with the Renewable Energy Storage Lab (RESL) at Dalhousie University to determine which of the four techniques is optimal for their primary market: off-grid solar storage. The present study will focus on one main element of this larger ongoing project.

The objective of this study is to measure and evaluate the time and energy requirements associated with each of the four formation techniques at Surrette. This is accomplished with an online measurement system that has been designed and constructed by the RESL. This system was installed at the Surrette factory in May 2014, and has since been recording key electrical currents and voltages within the formation machines while they operate. The recorded data is used to characterize the electrical conversion efficiency of the different formation machines that actually charge the batteries at Surrette. The total time and energy requirements for the formation of one common battery model are then compared for all four techniques. Upon completion of the entire project, this comparison will be part of a final recommendation that will be provided to Surrette, identifying which formation technique should be the prime candidate for future expansion at their factory.
Robust control is a type of system controller which is designed to mitigate the effects of uncertainty. Uncertainties can be classified as either disturbance signals or dynamic perturbations. Disturbance signals involve input or output disturbance, sensor noise, or actuator noise. Dynamic perturbations involve a mismatch between the dynamic system model and the actual system. This mismatch could be the result of unmodeled high-frequency dynamics, system nonlinearities, or parameter variations from wear or manufacturing.

With uncertain system parameters, there might be a certain combination of parameter values which can result in especially undesirable system behaviour. It is important to analyze these worst case scenarios in order to understand how the system could behave within the range of expected parameter values. MATLAB’s Robust Control Toolbox allows for analysis of these worst case combinations.

Robust control design can be carried out in MATLAB with the use of simple commands and weighting functions which allow for a multivariable sensitivity approach to signal error, controller effort, and magnitude of output over a range of different frequencies.
For autonomous systems the ability to travel through an unknown area is important. They must be able to create a map of this environment while also tracking their own movements through it. To create this map an autonomous system must be able to recognise a landmark it observes as being new and unique or the same landmark as previous viewed. This cataloging process is called data association. Data association is a critical component of simultaneous localization and mapping (SLAM). This is challenging in an underwater environment with an autonomous underwater vehicle (AUV) where currents can alter the AUV’s perceived location of landmarks used to update the AUV’s estimated position. In an effort to reduce false positives in the data association seafloor elevation trends local to SLAM landmarks are used as additional features to assist in verifying association between landmarks. Elevation gradients are less sensitive to sensor error and seafloor changes over time than other environmental features. Elevation are extracted from side-scan sonar data and new landmark elevation profiles are compared to previously observed ones to find the best associations. This presentation outlines the unique ability to identify the best match within a set of landmarks and is a good complementary feature to an existing data association algorithm.
High Resolution Measured Domestic Hot Water Consumption in Canadian Homes

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Keywords: domestic, hot water, DHW, consumption, building energy, simulation

In 2011, domestic hot water (DHW) heating accounted for 22% of Canadian residential energy use. In response, technologies such as solar hot water and solar combi-systems are being installed to reduce water heating energy consumption, however, their performance is greatly affected by DHW consumption patterns. To accurately predict the energy saving potential of these systems it is important to understand DHW consumption profiles. Due to the expensive nature of field studies, previous DHW consumption profiles have been generated synthetically using probabilistic modelling techniques or they have been generated using measured but limited datasets. Recently in Halifax, Nova Scotia, the Solar City program has made DHW consumption and DHW draw temperature measurements available for 199 homes at a time-step of 1 minute, along with a home survey of each participant to determine occupancy rates and other meta-data. The analysis of these data reveals consumption characteristics such as average daily consumption per household and per occupant as well as seasonal, monthly and daily variations in usage patterns. In addition, the range and variability of DHW draw temperature was determined.
A robotic manipulator is a multipurpose, programmable device which consist of multiple segments that performs tasks by interacting with its environment. These tasks can be very complex in cluttered environment conditions. Manipulators are required to move in the presence of fixed or even mobile obstacles, tracking a desired path without collisions. This can be done by using a suitable controller such as sliding mode controller, Adaptive controller and PID controller.

In this presentation several course projects in my directed studies are presented and discussed. In the first project an adaptive controller was used because of its ability to express the dynamic model of a n-linked manipulator as linear with respect to its parameters and also its ability to limit tracking error. The aim of the project was to track a given trajectory with minimal error. A simple fixed gain adaptive law was used to update the unknown parameters from the manipulator dynamics equation. The simulation results shows that the actual trajectory converges to the desired trajectory well below 0.5 seconds. As a result an accurate trajectory tracking was achieved.

The second project is to design a control law for a single mobile robot to follow an arbitrary path reference with predefined velocity profile. The resultant control system is stable. It was found that the robot followed the desired nonlinear trajectory with minimal error and hence the control objective was achieved.

The Robot Operating System(ROS) is a flexible framework for writing robot software. It is collection of tools and libraries which can be used for various robotic applications. Future work will focus on implementation of advance control algorithm in ROS for real time setup such as Cyton,a 7 dof manipulator and Pioneer 3dx, a mobile robot The setup is available in Advanced Control and Mechatronics Lab.
Measuring nm-scale MEMS Displacements from Degraded Images Using a FFT Optical Method

Presentation

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Keywords: MEMS, optical displacement measurements, image processing, FFT image analysis

This presentation examines the effect of artificial and physical blurring on the integrity of an image used in optical displacement measurements of MEMS devices. In order to obtain accurate in-plane displacement measurements the periodic structures used in a FFT based displacement measurement method must be clearly discernible. Two common forms of image degradation are: blurring caused by the dynamic (AC) motion of the actuator and focus effects due to changes in focal plane or media changes.

This presentation addresses whether the relevant features of an image are retained with heavy image degradation with respect to optical displacement measurement. The motion of MEMS thermal actuators were measured by taking a series of undegraded microphotographs at varying DC voltages. A FFT based algorithm was used to analyze the phase of periodic structures in the image and measure displacement with a precision on the order of 20-100nm. Pristine undegraded measurements were compared with both artificially blurred images as well as manually defocused images.

It was found that image integrity was not significantly affected by large amounts of blurring and defocussing.
System Identification and Model Predictive Control of a Hydraulic Motor-Valve System for Applications in Active Heave Compensation

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Keywords: MPC, system identification, nonlinear system, hydraulic valve

With respect to at-sea operations, an active heave compensation (AHC) system is a system which through active feedback decouples ship motion from the motion of an object or device attached to the ship. One of the first, and still very common uses of an AHC system is to decouple the motion of an oil rig floating at the ocean surface from the motion of an attached drill which is penetrating the ocean floor. Since the initial development of AHC systems used primarily in oil drilling, AHC systems have spread to many areas of ocean engineering including: vessel-to-vessel payload transfer, towed sonar arrays, autonomous tethered robots, and high sea-state personnel transfers. For many of these AHC systems the control method applied would be a feed-forward controller, perhaps coupled with a PID control scheme or a state-feedback controller. In this presentation the application of model-predictive control (MPC), instead of the previously mentioned control methods, is examined in operating a nonlinear hydraulic motor-valve system. The hydraulic motor-valve system is analogous to an AHC winch system with no load applied. Hydraulic pressure and flow data were collected along with motor velocity data for different valve openings allowing system identification and the creation of a linearized system model. The system model was validated and used to create an MPC controller on a National Instruments myRIO embedded system which was then used to control the real-world motor-valve system. Preliminary results of successfully applying MPC to the motor-valve system are presented with discussion of methods to improve performance and correct for nonlinear response of the hydraulic valve.
A significant amount of people in the world are without electricity service, the majority of which are located in rural areas where extending the electricity grid is not economically feasible. Off-grid solar photovoltaic technology has been identified as the most prominent option to electrify these rural areas, of which lead-acid storage batteries are a major component.

The formation process of lead-acid batteries is poorly defined in the public literature as it is considered confidential by battery manufacturers. Thus, the objective of this study is to determine the lead-acid battery characteristics of amp-hour capacity, voltage, temperature, and internal resistance as a function of formation level during deep-cycling operation, with the goal of identifying the optimal formation level for off-grid solar applications. In order to study the impact of the formation algorithm on subsequent cell performance, two different formation algorithms are considered: a constant-current formation algorithm, and multi-step current formation algorithm. For both formation algorithms, the one-shot container formation method is used.

Eight cells are formed using the constant-current formation algorithm, and seven cells are formed using the multi-step current formation algorithm. For both formation algorithms, cells are formed in series to a different formation level in order to capture a wide range of formation levels. For a positive plate thickness of 4.32 mm, the optimal formation level for off-grid solar applications is determined to be 2.85 times the theoretical capacity of the cell using the constant-current formation algorithm, and 3.10 times the theoretical capacity of the cell using the multi-step current formation algorithm. This formation range extends beyond the range recommended in literature of 1.24 to 2.50 times the theoretical capacity of the cell.
Nickolas Tesla developed the first bladeless turbomachine design in 1913, including the Tesla pump, for which he obtained a US patent #1,061,142. In the early days of its invention it was regarded as a conceptual design due to issues in efficiency compared to traditional bladed turbomachinery.

A Tesla pump’s impeller or disk pack consists of smooth, flat parallel disks on a drive shaft, arranged such that there are small spaces between the disks. The fluid that is forced into the small spaces between the disks moves outwards from the center of the disk pack, and spirals out, similar to that of a centrifugal type pump. Unlike centrifugal pumps, the working principle of a Tesla pump involves viscous drag, or shear forces in the fluid; mainly occurring within the boundary layers on the surface of the disks. For a Tesla pump the fluid is dragged along the surface of the rotating disks, accelerating with the disk until it reaches the disk’s velocity and out of the pump.

A prototype Tesla pump was designed and built with the objective of continuous operation under large amounts of vibrations, building on its known lower sensitivity to cavitation, and better reliability than a conventional bladed pump. A continuous test loop was assembled and used to create pump curves to determine the operational characteristics of the pump, such as the effect of different disk pack spacing’s and rotational speeds on performance. Tested to date are four disk pack spacing’s, three motor speeds, and at two different vibration frequencies.

Preliminary results show that the prototype produced a maximum approximate flow rate of 1.25 L/min, with a max head of 1.8 m and efficiency of 1.5%. This was obtained at the highest motor speed (3600 RPM) and the smallest spacing tested (5 thou). When the motor speed was decreased, the performance of the pump also decreased. Similarly as the disk pack spacing increased the performance decreased. Little to no effect on pump performance due to vibration was found in the preliminary tests done under two different vibrational frequencies. Further research and experiments are needed to further characterize the performance of the pump and determine optimal pump configurations.
Interfacial Mass Transfer Effects on Supercooling Salt Hydrate Heat Storage Performance

Presentation

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Keywords: Internal convection, heat transfer, mass transfer, phase change materials, numerical simulations

The incongruent phase change behaviour (i.e., concentration and temperature dependent) of salt hydrate solutions in water makes them susceptible to changes in composition induced by mass transfer at an interface (e.g., condensation/evaporation of water). Changes in interfacial composition propagate throughout the solution by diffusion (weak) and by internal convection (strong). Diffusion promotes composition stratification of the solution, whereas convection promotes mixing.

Prototype supercooling heat storage experiments conducted in a unsealed enclosure using diluted aqueous sodium acetate trihydrate (88 % mass) have shown cycle-induced composition stratification in the solution, confirmed by non-uniformities in the solidification temperatures recorded by thermocouple. Stratification has sometimes caused undesired anhydrous salt crystallization, adversely affecting the solution’s ability to supercool for long durations.

Numerical simulations were conducted in COMSOL Multiphysics 4.4 to study parameters affecting interfacial mass transfer of water vapour in the enclosure with details of their effects on internal circulation/mixing. The simulation results were used to identify the principal mechanism responsible for the stratification and inform design improvements for a new enclosure that does not suffer from stratification effects.
Nonlinear Adaptive Robust Control for Bilateral Telerobotic Systems

Presentation

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Keywords: Bilateral teleoperation, Time delays, Nonlinear control, Adaptive robust control, Robotic manipulators

In case of some tasks that needs to be operated in a remote environment, bilateral teleoperation is a commonly used strategy. In teleoperation, a human operator conducts a task in a remote environment via master and slave hardwares. The operator sends a command to the slave side through operating the master, then this command transmitted through the communication channel to the slave subsystems with interaction with the environment. Likewise, the forces sensed at the environment are transmitted back through those subsystems, to the human operator.

The communication time delay is one of the main constraints in bilateral teleoperation systems. Many different kinds of control methods have been developed to solve this issue. Most of the methods are based on passivity theory. For example, Scattering schemes, which proposed by Anderson and Spong, is based on passivity theory. Another commonly used passivity based approach is wave variable formulation, which is proposed by Neimeyer and Slotine. These passivity based approaches could guarantee the passivity of the bilateral teleoperation system. However, for the bilateral teleoperation system with varying time delay, the passivity based approaches cannot preserve the passivity of the system anymore.

In my research work, a new adaptive robust control design approach for nonlinear teleoperation system with varying asymmetric time delay is presented. This control scheme is dealing with the asymptotic stability of the bilateral teleoperation system with any bounded, time-varying delay with a bounded rate of variation. At the same time, the transparency and the synchronization of the teleoperation system are also guaranteed.

The real implementation of the adaptive robust control approach will take place in the future. The experiment is designed to develop on two Phantom Omni Haptic devices. The comparative results will be recorded to verify that the proposed control algorithm could achieves an excellent control performance and a guaranteed robust stability simultaneously under bounded time-varying time delays.
The focus of this research is on hole making in composite materials. These holes are important as they are used to assemble composite material components together and must be done in such a way as not to impact the strength of the part too greatly and because they are time consuming to create. A twist drill is the most common method to generate holes. From a metal removal perspective, it is also one of the most complex operations combining a piercing operation at the tip of the tool with a cutting operation along the cutting edges of the drill. Additional complexity arises, when machining Carbon Fiber Reinforced Plastics (CFRP) due to the anisotropy and inhomogeneous nature of CFRP compared to conventional metals. During a drilling operation, debonding of the layers of reinforcement or plies in addition to delamination at the drill bit entrance and exit surfaces on the composite component may occur effecting the strength and the appearance of surfaces of the component. Delamination and burr defects can significantly affect the cost, accuracy and the reliability of manufactured holes especially in the aerospace industry where precision is required. Thus, understanding key factors effecting hole qualities are very important to establish effective hole machining strategies. To this end, this project will investigate and evaluate the influence of different cutting parameters such as the cutting feed and the cutting speed on the structure of CFRP specimens and to provide a better understanding of the delamination phenomena, and to reduce or eliminate the drilling induced damages and defects in CFRP.

To this date, the experimental setup has been designed and built. Preliminary experiments have been conducted to verify the setup effectiveness. A Mori Seiki MV Junior CNC milling machine will be used for hole drilling. Three different cutting tool materials and geometries will be used. Cutting forces and torques will be measured using the JR3 force & moment sensor integrated with a National Instrument data acquisition system. The dimensional tolerance and accuracy of the drilled holes will be measured using a Mitutoyo BHN305 Coordinate Measurement Machine (CMM). A Nanovea PS50 non-contact optical profiler will be used for surface finish quality checks.
Ultra-Supercritical Boiler Firing Systems Comparison
Presentation

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Keywords: Ultra-Supercritical, Boiler, Circulating Fluidized Bed, Pulverized Coal

Most of the world’s coal fired power plants use Pulverized Coal technology (PC), however, due to its fuel flexibility and other advantages, Circulating Fluidized Bed (CFB) is increasing. CFB is more suitable for Supercritical (SC) and Ultra-Supercritical (USC) Boilers. This study will focus on comparison between the two technologies SCPC and CFBSC boilers such as efficiency, availability and materials selection. Moreover, water, auxiliary power and sorbent consumption will be presented in both firing system.

USC features and problems will be studied for PC and CFB for example effect on cost and efficiency by utilizing different tubing system, vertical or wrapped around, normal or rifled tubes.
Passively adaptive tidal turbine blades made of composite materials can be tailored to couple flap-wise bending deformation with span-wise twisting (bend-twist coupling). This allows the angle of attack of the blade to passively adapt as a function of hydrodynamic loading. Bend-twist (BT) coupling can decrease loads on the blades and structure, and potentially regulate power production; both of which can lead to a more cost effective turbine. Decreased blade loads means longer blades can be used with the same support structure, resulting in more power production without a significant increase in capital cost. A coupled iterative finite element-blade element momentum theory (FEM-BEMT) tool for the design of BT blades has been developed through this work. This design tool considers both structural aspects (materials, composite layups and stresses) and hydrodynamic performance (power and thrust loads) of BT blades. It also decreases the computational time and cost between design iterations compared to computational fluid dynamics-FEM coupled codes, making it ideal for early stage blade design where many configurations are trialed.
Monitoring of Subsea Cable Termination for Tidal Power Transmission
Using AHRS Sensor Installed in Subsea Termination End

Presentation

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Keywords: monitoring, tidal energy, power transmission cable, AHRS

The Minas Passage in the Bay of Fundy experiences extremely high tidal currents making it an ideal location to capture energy using tidal turbines. This same tidal regime also creates many difficulties in the installation of subsea equipment including transmission cables. In order to transmit power from a tidal turbine to the electrical grid a subsea transmission cable is required. Although the installation of subsea cables is an established and well understood process, installations in high current tides are not. The Fundy Ocean Research Center for Energy (FORCE) has installed four power transmission cables in the Bay of Fundy. In order to assure turbine developers a reliable mode of electrical transmission exists at the site, a method for monitoring the cable termination end is necessary. To monitor the state of the subsea cable termination end an instrumentation package was installed with two of the cables before deployment. An attitude heading reference system (AHRS) sensor installed in the instrumentation package measures the orientation and accelerations of the cable termination. Analysing the orientation data can determine how the cable has settled following deployment and whether this orientation has remained stable. Changes in orientation data and acceleration data from the sensor can be analysed to determine if the cable termination has moved due to forces from the tidal current. This data analysis from the cable termination instrumentation package allows the determination that the subsea cable termination ends are stable and prepared for recovery and connection operations during turbine deployments at the FORCE test site. Prior to the installation of the instrumentation package static and dynamic measurements were recorded to validate the recorded data. Uncertainty of orientation angles and velocity are determined from these measurements. Simulated sample data is used to identify cable termination movement events in larger simulated sample datasets.
As electricity rates rise, off-grid solar photovoltaic (PV) power systems will play a major role in the infrastructure of many developing countries. Concerns on about the battery life, and its long term costs, in an off-grid system is often cited by customers as a hindrance to the adoption of this technology. In many off-grid solar systems, including solar powered street lights, Valve Regulated Lead Acid (VRLA) batteries are used as the energy storage mechanism.

The purpose of the research is to identify commercially viable mechanisms to increase the life of VRLA batteries in off-grid solar systems. Battery life will be assessed through accelerated life testing. The following mechanisms will be tested to assess their impact on battery life: charging algorithm including time, voltage, temperature compensation, and frequency of conditioning charges; passive temperature mitigation; and PV to load ratio.

Testing has been conducted in the lab with an Absorbed Glass Matt (AGM) VRLA battery to determine the baseline charging parameters when used in a solar powered street light application. An instrumented solar street lighting system is being monitored to verify if the baseline values determined in the lab show similar results in a real life application. Once this has been established, an accelerated life cycle test will take place and the battery failure mode identified. The failure mode of the battery will guide the selection of which mechanisms will be tested to increase battery life. The different life extension mechanisms will then be tested and compared to the expected results.
Thermal behaviour analysis of tablet computers
Poster

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Keywords: electronic cooling, tablet computers, temperature measurement, thermal imaging

The first step in developing a novel temperature control technology for tablet computers is to analyze and understand the thermal behavior of the device at different operating conditions and usage load. The prime objective of this study is to develop an accurate methodology to predict the transient temperature response of two popular tablet computers; Dell Venue 8 Pro (Windows OS) and Samsung Galaxy Note 8 (Android OS). Both tablets were subjected to two different types of applications to mimic regular usage load and heavy stressed load by using Skype and two benchmarking application (HeavyLoad for Windows and StabilityTest for Android) respectively. In the preliminary experiment only one type-T thermocouple was attached to a high temperature region in the back surface which was determined by the inspection of internal circuitry. A Skype video call of about 100 minutes was carried out between tablet PCs and temperature curves were generated. In the second experiment, thermal behavior at intermittent operation was studied. Skype video calling between tablet PCs up to 67 minutes following 5 minutes of “on call” and 10 minutes of “off call” pattern was conducted repeatedly. However, in this test, tablet PCs were solely battery powered. In the third experiment both tablet PCs were subjected to stress test for 150 minutes of continuous benchmarking operation. As benchmarking operation consumes much power, this test was conducted while charging to avoid battery depletion. Maximum temperatures encountered were 51°C and 41°C for Windows and Android tablet respectively. In the next phase of experimentation, five type-T thermocouples were attached to the back surface of both tablets. A similar stress test as before was conducted for 125 minutes. The reason for using five thermocouples for each tablet was to generate a rough temperature profile of their back surface. Using a MATLAB script of inverse distance weighted (IDW) interpolation, temperature contour of the back surface for both tablets were generated. For better understanding and comparison, a thermal imaging camera was also used to take thermal images at the same operating conditions. As IDW interpolation technique has errors associated with it, deviation of predicted temperature from the original data was also observed by investigating thermal images and IDW contour plots. Thermal analysis by opening up the tablets will also be done to observe heat spreading in non-heat generating components (i.e. display, stiffener, PCB, etc.) from heat sources. Results obtained in this study will be used to develop proper numerical models and bench-top experimental setup mimicking the thermal behavior of tablet PCs.
Wild blueberries are naturally grown crop and developed from abandoned farm land or cleared wood lots. Producers manage the competing vegetation and plant disease by applying herbicides and fungicides uniformly without considering the substantial variation in weed density and plant coverage. Blanket applications of these agrochemicals has increased the cost of production while excess spray in non-target areas leads to excess environmental contamination. The use of precision agriculture technologies has the ability to allow producers to apply agrochemicals in only select areas in the field where needed at the ideal application rate.

A prototype variable rate smart sprayer was developed for spot-application of herbicides and fungicides in the specific section of the 13.7 m sprayer boom where the weeds or blueberry plants have been detected. The boom was divided into 20 individually controlled sections featuring 27 nozzles with a 0.5 m spacing. The variable rate control system consisted of nine digital color cameras mounted 0.15 m in front of the sprayer nozzles, a 20-channel MidTech Legacy 6000 controller and a custom 20-channel variable rate controller. Cameras were connected via USB cables to a computer. The cameras were capable of taking the images in real-time. Custom software was developed and incorporated into the computer for processing the images to detect weeds and blueberries in real-time. The triggering signals were sent to the variable rate controller to open the specific nozzles where the weeds or blueberry plants had been detected. The variable rate sprayer was developed to allow farmers to convert their uniform sprayers to one that can operate on a site-specific basis. The modifications required to convert each sprayer is estimated at $25,000. Cost savings suggest a payback period of less than two years for a grower with 100 ha of blueberry land coverage. Additional benefits include; lower maximum residual levels on harvested blueberries, time and labor savings and lower environmental impact.
The principal control objective of space conditioning systems in buildings is to maintain thermal comfort while minimizing energy consumption and costs. Model predictive control (MPC) is a recent development that uses modelling and simulation with forecast conditions to exploit building thermal mass in an effort to improve indoor thermal comfort and reduce energy use/cost compared with traditional control strategies. This paper takes a LEED Silver building and applies a MPC strategy to it. The building is modelled with EnergyPlus, which is then compared to consumption data for model calibration. The building uses a common loop heat pump system to distribute energy throughout the building. The calibrated model is then exercised under various control strategies to generate data to create and train a statistical black box model. The black box model is then used as the base model for the model predictive controller, while EnergyPlus is used as a virtual building. The MPC strategy is run for an entire year to verify performance. The resulting MPC strategy results are compared to the existing rule-based control applied to the building to highlight the energy savings gained by using MPC. Initial results indicate a 10% overall HVAC energy reduction, with a 7% drop in space heating steam and an 11% drop in HVAC electricity. While the energy reduction is small, it is done on a new LEED certified building, and requires no changes to the equipment, just a new software routine for the building energy management system.
Notes: