McGill Engineering Research Showcase

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Poster Abstracts 2017

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ADVANCED MATERIALS AND NANOTECHNOLOGY

Evaluation of the “Modified-Hidden-Gap” Connection for Square HSS Brace Members

By Mohamed Afifi and Professor Colin Rogers

Hollow structural sections are connected to joint of concentrically braced frame utilizing slotted tube-to-gusset plate connection. A net area is created because of slot and shear lag is available because of unconnected parts of tube. Tensile rupture of net section of brace is the controlling failure mode when seismic capacity design counts are connected; also, existing connection reinforcement plans have ended up being uneconomic for seismic application.

The "Modified-Hidden-Gap (MHG)" connection, in which a notch is made in the gusset plate speaks to an appealing option to customary connection reinforcements; notwithstanding, no design rules exist for the MHG connection for square HSS braces. Hence, this project depicts the finite element modeling and laboratory testing to decide dimensions required to achieve yield resistance of brace. Based on results, guidelines for designing economical full-strength Modified Hidden Gap (MHG) connections will be developed for use in seismic design.

Effect of Repetition Rate on Femtosecond Laser-Induced Homogenous Microstructures

By Sanchari Biswas and Professor Anne Kietzig

Direct laser micromachining has emerged as a versatile technique allowing extensive modification of material surface properties. These modifications are brought about by the laser material interaction and therefore for efficient replication of the desired surface properties for industrial usage, requires extensive knowledge of the factors affecting laser material interaction. Here we demonstrate the effect of the laser repetition rate on machining outcome; one of the various factors crucial for efficient industrial transfer. We report on the micromachining outcome on copper (Cu) and titanium (Ti) using femtosecond pulses (<100fs) at 1 and 10 kHz. The microstructure formation and the variation in the surface texture (coarseness) caused by the differences in the two repetition rates were analyzed and compared using the accumulated fluence model and lacunarity study, respectively. Significant differences in the coarseness of the microstructure and in their threshold fluence were observed in both the metals at the two repetition rates. These differences were successfully attributed to the respective material behavior at the two repetition rates. For laser surface texturing industries our study provides a first- hand knowledge in understanding the effects of the laser repetition rate on the textured microstructures.

Composite Recycling Innovations

By Sean Bolduc and Professor Larry Lessard

McGill’s Structures and Composite Materials Laboratory is currently conducting research that hopes to provide recycling solutions for the ever-increasing composite material waste stream. We are exploring a broad range of waste sources, as well as a number of viable applications. On one hand, we are testing the feasibility of using recycled plastic bags in combination with recovered banana fibers left over from the cultivation process to make composite panels for basic housing applications in third world countries. At the same time, we also hope to meet the growing need for recycling solutions within the aerospace industry. To this end, we are investigating the possibility of reusing waste generated during the manufacturing of composite aircraft structures by using the compression moulding process to make small intricate components.

Studies on Randomly Oriented Strand (ROS) Composites for Aerospace Applications

By Vincent Cadran and Professor Larry Lessard

Randomly oriented strand (ROS) composites, a material architecture with discontinuous chips of long fibres, demonstrate enormous potential to replace complex shaped metallic structures with light weight composites for aerospace applications. The randomly-oriented strands possess excellent formability, nearly isotropic properties, high specific stiffness, and offer short processing times when coupled with low-cost manufacturing techniques such as Compression Moulding. However, the random nature of the strand placement also creates challenges, particularly for predicting final part shape and mechanical strength.

Ongoing work addresses both the processing and mechanical characterization of ROS carbon fibre/polyetheretherketone (PEEK) composites. In terms of processing, the effects of processing conditions and part geometry on the dimensional stability of thin gauge parts are observed. Preliminary simulations have been compiled to predict trends between part thickness and final part warpage. Working towards mechanical characterization, models have been developed to assess the stiffness, strength, and fracture propagation of specimen under tensile loads.

Molecular Dynamics Study of the Self-Assembly of Dilute Binary Chromonic Liquid Crystal Mixtures

By Oscar Matus Rivas and Professor Alejandro Rey

Aggregation of dilute equimolar binary mixtures of lyotropic chromonic liquid crystals (LCLCs) was studied employing molecular dynamics simulations. The effect of molecular shape, conformational flexibility and hydrogen bonding capability of three LCLCs mesogens was investigated. Structural characterization, along with hydrogen bond distribution analysis and solvent accessible surface area calculations were carried out. It was found that each mixture presented an individual molecular segregation state where the number of pi-pi stacks between different LCLC species was minimized. Aggregation of LCLCs mixtures depends on mesogens' cross-sectional area differences and distribution of polarizing groups. These molecular features contributed to achieving different mixture segregation patterns. Therefore, mesogens with similar long axis molecular length and high hydrogen bonding density represent a promising alternative for the preparation of LCLCs binary mixtures. These results contribute to the atomic-level understanding of LCLCs general aggregation rules which are essential for the engineering of innovative LCLCs supramolecular applications.

Graphene-Polymer Nanocomposites: Rheological, Electrical and Mechanical Properties

By Natassia Batista, E. Helal, R.S. Kurusu, and Professor Pascal Hubert

The goal of this collaborative project is to develop new robust graphene-polymer nanocomposite systems for industrial applications. Low cost commercial graphene produced by NanoXplore are combined to polymers by conventional melt-compounding. The research team from McGill University and Ecole de Technologie Superieure use state-of-the-art characterization methods to evaluate the material performance. Rheological and electrical percolation thresholds for graphene-high-density polyethylene nanocomposites were identified and the improvement of mechanical properties was very promising.

Amphiphilic Block Copolymers as Methane Hydrate Kinetic Inhibitors

By Faraz Rajput, Professor Phillip Servio, and Professor Milan Maric

Under appropriate conditions, formation of gas hydrate plugs in pipelines becomes problematic due to damaging pipelines as well as the equipment in the process downstream. In these cases, the prevention of gas hydrate formation becomes crucial. To investigate the inhibition potential of kinetic hydrate inhibitors (KHI) on a methane-water gas hydrate system, amphiphilic block copolymers, acting as macrosurfactants, were synthesized to include hydrophobic and hydrophilic properties. A PVA-PS block copolymer inhibited hydrate growth comparable to the industrially used PVP inhibitor. By substituting PS with a more hydrophobic PPFS as the short end group, the methane hydrate growth rate further decreased from the PVA-PS system, resulting in greater inhibition than the PVP homopolymer. Similar trends were observed with PVP based amphiphilic KHI with added hydrophobic caps. Increased hydrate inhibition with increasingly hydrophobic head groups further emphasizes the role of the structure of the KHI on its inhibition potential.

AEROSPACE ENGINEERING

Transient Electron Beam Energy Absorption of Solid 304 Stainless Steel: Simulations and In Situ Measurements

By Paul Carriere and Professor Stephen Yue

Electron beam powder bed fusion (EB-PBF) presents significant challenges, as over 50 independent process variables can impact the finished part. In commercial systems, restricted access to the relevant beam parameters has made parametric analysis difficult, and in some cases, impossible. This work focuses on intrinsic matter/electron interactions by analyzing the relationship between beam parameters, energy absorption and heat conduction. Using calibrated pulses at different accelerating voltages (60, 80kV), beam currents(10, 20mA), and pulse lengths(0.6-9.2mS); in-situ temperature measurements determine the energy absorption via curve fitting to an analytical function. Monte-Carlo electron interaction software CASINO is used to predict the energy loss due to back-scattered electrons. Using energy conservation, this research shows for the first time that CASINO can a priori predict the dominate energy loss mechanism, with agreement between theory and experiment within 4%. This opens new applications for CASINO in EB-in heat and charge transfer analysis.

Spreadability and Surface Conditions for Additive Manufacturing Process

By Basel Alchikh-Sulaiman and Professor Stephen Yue

Melting of metallic powders with electron beam energy has been utilized extensively to produce parts for aerospace industry. Powders can be consolidated in several ways, but currently additive manufacturing (AM) is under a serious consideration. Additive manufacturing begins with a CAD description of the component. Using this file, the machine lays down successive layers of powders in a layer-upon-layer fashion to generate the required 3D object. The research aim of my project is to understand the spreading mechanism of spherical titanium powders for a single-layer part. Mechanism of spreading is not fully understood and it is an essential step to control production of parts. Electron beam melting process needs very small size of particles to generate layers with a defined height. The height of a single layer of powder should be 100 µm, and the recommended particle size distribution for electron beam melting is 45 to 106 µm.

Effect of Heat Treatment on γ' Precipitation and Hardness in a Ni-Based Superalloys

By Christina Maria Katsari and Professor Stephen Yue

Superalloys have been used for many years in the aerospace industry due to their excellent creep performance in high temperature and high stress environments. The precipitation that contributes to creep resistance also increases the strength; however, this gives rise to thermomechanical processing issues. Therefore, the ultimate goal of this work is to understand the precipitation characteristics in order to design heat treatments that make thermomechanical processing easier without compromising the final microstructure and properties. The main precipitate that was examined was the gamma prime phase (γ') [Ni_3 (Al,Ti)], which largely determines the mechanical properties of the alloy. The γ' was found to form in three different sizes; primary, secondary and tertiary. The differences in the volume fraction and morphology of each precipitate type were noted and the relationship between heat treatment and precipitates will be discussed.

Hydrogen Embrittlement Susceptibility of High Strength Materials Based on Experimental Investigations & Finite Element Analysis

By Tuhin Das and Professor Stephen Yue, and Professor Jun Song

Ultra-high strength steels are used to manufacture landing gears while critical engine components are made from nickel base superalloys. These materials are also frequently used to manufacture fastener components in aerospace industries. But these materials fail prematurely under certain exposure to hydrogen due to hydrogen embrittlement (HE) leading to the total loss of integrity of structures which could be catastrophic. Therefore, in the present study, a combined approach involving experimental investigations and finite element analysis (FEA) has been taken to develop a better understanding of HE failures in relation to material susceptibility based on some simplifications of ASTM F1624 standard test method. This approach also aims to discuss possible mitigations to HE problem by reducing susceptibility of the material to HE.

Advanced Design and Manufacturing Technologies for Complex Composite Structures

By Linus Lehnert and Professor Pascal Hubert

Fiber reinforced polymer structures find many applications where weight and cost must be kept at a minimum without compromise on mechanical properties. Current state of the art in the aerospace industry favors the development of assemblies with a high volume of sub-components that require numerous processing and assembly operations. The primary objective of the project is to further the development of next generation complex, one shot, composite structures for low to medium production volumes in the aerospace industry. The research focuses on three technological axis, namely preforming technology, additive manufacturing and design optimization to fabricate net shape composite parts by Resin Transfer Molding (RTM). With the collaboration of industrial partners, the developed technologies will be applied to fabricate a prototype product showcasing the advantages of this innovative manufacturing methodology.

New Composites Material for Space Applications

By Diane Liu, Julieta Barroeta-Robles, and Professor Pascal Hubert

The goal of our project is to evaluate several new composite materials for space applications using an out-of-autoclave manufacturing approach. The first part of the project involves identifying the needs, determining the available materials, and ranking the materials (Diane Liu – PhD Candidate). The second part is about processing issues: a) resin characterization (Julieta Barroeta Robles - Master's student) and b) prepreg/ laminate panel characterization and sandwich panel characterization (Diane Liu – PhD Candidate). Finally, performance issues are investigated and mechanical tests are performed in the third part of the project (Concordia University). The fourth and final part of the project involves creating demonstrators, where representative laminate and sandwich panels are made to demonstrate proof of concept (all students).

Kalman Filter Based Unconstrained and Constrained Extremum-Seeking Guidance on SO(3)

By Alex Walsh and Professor James Forbes

Extremum-seeking guidance endeavours to drive the output of a system to the extremum of an unknown objective function. This work proposes an extremum-seeking guidance algorithm on SO(3) for cases with and without inclusion and exclusion zones. The gradient of the unknown objective function is estimated via a Kalman filter so that the extremum of the objective function can be approximated. To satisfy inclusion and exclusion zone constraints, two different constrained Kalman filters are proposed. The first Kalman filter is a gain-projected Kalman filter, and the second is a novel linear matrix inequality based Kalman filter that is able to accommodate a larger class of constraints. The proposed extremum-seeking guidance algorithm is demonstrated using a performance objective relates a spacecraft's attitude, to received power of an unknown radiation source using a patch antenna.

Payload Recovery from High Altitude Using Autonomously Guided Parafoil

By Charles Cossette and Professor James Forbes

The project's goal was to design, develop, and build an autonomous aerial vehicle that would navigate through the air by use of a steerable parachute (parafoil). Development of such a device would allow easy recovery of weather balloons and rockets, as well as precision aerial delivery of cargo intended to land at specific coordinates. A functional device was built and tested through Summer 2017, using student built flight computers and a PD control law for navigation.

Computational Modeling of Ice Accretion on a Helicopter

By Maged Yassin, M. Nathoo, J. Anthony, Professor Wagdi Habashi, and M. Fossati

Ice accretion on helicopter rotors have detrimental effects on its aerodynamic performance due to alterations in the blade geometry. While CFD methods for helicopter aerodynamics have significantly progressed, simulating the multi-physics of rotorcraft in-flight icing is still a challenging task. The current work introduces supercomputers-based computational approaches capable of assessing the impact of ice accretion on a rotorcraft's aerodynamics, blade dynamics, vibrations and loading. 3D advanced mesh manipulation techniques are developed to account for dynamic ice accretion and for the simultaneous solution of flow over rotating and non-rotating parts. The rigid and elastic motions of the blades are accounted for through a loose coupling between the flow solver and a multi-body dynamics solver. Additionally, a tool capable of tracking shed ice is developed. A number of test cases are presented demonstrating the capabilities of these new tools.

Computational Fluid Dynamics of Future Hypersonic Transport Aircraft

By Song Gao, J. Seguin, W. Zhang, Professor Wagdi Habashi, and M. Fossati

In another decade or two, civil transport at 10 to 20 times the speed of sound may become a reality. In such hypersonic flight regimes, the temperature in the shock layer initiates chemical reactions such as dissociation, and the collisions among the gas molecules become energetic enough to populate vibrational and electronic energy levels. Moreover, the bow shock at the nose of the vehicle triggers ionization, opening the door to electromagnetic technologies that boost aerodynamic performance. The goal of this project is to develop advanced supercomputers-based computational approaches that model flow from low subsonic speeds all the way to non-equilibrium hypersonic speeds. Chemical and thermal non-equilibrium, as well as magneto-hydrodynamics, are solved in a loosely-coupled manner with the Navier-Stokes equations resulting in a robust multi-physics solver. Test cases are presented that demonstrate the unique capabilities of the proposed methodology.

BIOENGINEERING

Multi-Objective Optimization of Drug Carrying Nanoparticles for Enhanced Cancer Therapies

By Ibrahim Chamseddine and Professor Michael Kokkolaras

Nanotherapy is a cancer treatment method that uses nanoparticles as drug carriers to target tumors, thus reducing the damage of healthy tissues as compared to other methods such as chemo- and radio- therapies. The efficacy of the treatment is highly dependent on the nanoparticle structure. In this study, nanoparticle design optimization is performed to minimize the treatment toxicity while maximizing the tumor reduction rate. For this purpose, we developed a computational model to quantify the accumulation of nanoparticles at the tumor, and the release of the drug into the cancerous tissue. We then used the derivative free Mesh Adaptive Direct Search algorithm to obtain the optimal nanoparticle design. Results showed that a nanoparticle size of 720 nm and aspect ratio of 7.45 yield 96.8% of the injected nanoparticles to adhere to the tumor, while attaining 50% uniformity in drug distribution. This study provides an insight on the nanoparticle structures that have the potential to clinically enhance tumor regression at lower systemic toxicity.

Extents, Locations and Geometrical Configurations of Calcification in Abdominal Aortic Aneurysm

By Zinan He and Professor Rosaire Mongrain

Calcification (Ca) is one of the main characteristic of aortic wall degeneration, and often associates with the risk of aneurysm rupture and the failure of endovascular repairs (EVAR). It is hypothesized that, not only the intrinsic properties of Ca, but also the location and the geometrical configuration of Ca may alter the global behaviour of the aortic wall. In this study, a quantitative and qualitative analysis has been performed over 100 patients having abdominal aortic aneurysm (AAA), to analyze the potential morphological effects of Ca on AAA.

Dual Laser Trap for Investigating Cell Mechanics over Different Length Scales

By Loic Chaubet and Professor Adam G. Hendricks

The cytoskeleton is a dynamic network of biopolymers that tunes the mechanical properties of the cell. The cytoskeleton plays essential roles in key processes such as cell division and motility. We have developed methods to examine the mechanical properties of the cellular environment using an optical trap, where a focused laser is used to manipulate a micron-sized bead inside the cell. To examine cell mechanics over different time and length scales, we developed dual optical trapping, a novel method where two beads are trapped simultaneously. One is oscillated while the other, some distance away, is used to detect the transmitted perturbations. Preliminary results in water and PEG solution validating this method were obtained, demonstrating the potential of this method to investigate cellular viscoelasticity and to provide insights into how mechanical signals are transmitted across the cytoskeletal network.

Bundling of Acetylated Microtubules Drives Enhanced Kinesin-1 Motility

By Linda Balabanian and Professor Adam G. Hendricks

Kinesin motor proteins transport organelles, proteins, and signalling molecules along microtubules. In addition to serving as tracks for transport, the microtubule cytoskeleton directs intracellular trafficking by regulating the activity of motor proteins through network organization, microtubule-associated proteins, and tubulin post-translational modifications. However, it is not well understood how these factors influence motor motility, and in vitro assays and live cell observations often produce disparate results. To systematically examine the factors that contribute to cytoskeleton-based regulation of motor proteins, we extracted intact microtubule networks from cells and tracked the motility of single fluorescently-labeled motor proteins on these cytoskeletons. We find that acetylated microtubules are predominantly bundled, and bundling enhances kinesin run lengths. The neuronal MAP tau binds preferentially on the highly curved regions of microtubules where it strongly inhibits kinesin motility. These results suggest that the organization of the microtubule network is a key contributor to the regulation of motor-based transport.

Combinatorial Peptide-Antibody Biofunctionalization Approach to Improve Vascular Substitute Performance

By Mariève Boulanger and Professor Corinne Hoesli

Cardiovascular disease is the leading cause of death worldwide. In case of atherosclerosis, vascular substitutes such as stents can be used to reopen narrowed blood vessels. The most common complications observed with these substitutes are thrombosis and restenosis. The incidence of these events could be reduced by developing pro-healing surface that captures endothelial progenitor cells (EPCs) from the blood flow to promote endogenous repair mechanisms. We

hypothesize that combining capture antibodies with extracellular matrix-derived peptides could maximize both the EPC capture and expansion steps.
A combinatorial microassay is under development to investigate the effect of various peptide/antibody combination on EPC behavior. Preliminary findings indicated that RGD-functionalized surfaces promoted cell expansion, while both the RGD and the anti-CD31 antibody surfaces enhanced EPC capture. This microassay may be used to screen the effects of a variety of antibody/peptide combination and lead to the development of the next generation of vascular substitutes.

Microencapsulation of Pancreatic Islet Cells for Type 1 Diabetes Treatment
By Christina Bitar and Professor Corinne Hoesli
Type 1 diabetes is an autoimmune illness, where the pancreas produces little to no insulin, causing an increase in blood glucose levels. Islet transplantation is an alternative treatment to periodic insulin injections. However, it requires lifelong immunosuppression to avoid islet rejection, which carries undesirable side effects. Alternatively, islet encapsulation in alginate microbeads eliminates the need for immunosuppressants. We developed a microchannel emulsification (MCE) device that produces alginate beads using a continuous phase, dispersed alginate phase, and a hydrophobic microchannel plate. Careful selection of the continuous phase was conducted by optimizing the interfacial tension and buoyancy forces between the continuous and dispersed phases. NovecTM 7500 Engineered Fluid was selected since it had the lowest interfacial tension and highest density difference with the dispersed phase, compared to light mineral oil and glyceryl trioleate. The MCE device can produce alginate beads of ~1.8 mm in diameter with a coefficient of variation of ~10%.

Antibacterial Properties of Hydrophobic Ionic Liquids
By Nicholas Lin, Professor Nathalie Tufenkji, and Professor Robin Rogers
Antibacterial resistance has made bacterial contamination difficult to eradicate. New antibacterial strategies are in need. However, any proposal of novel antibacterial materials should first weigh the trade-offs of minimizing the material's inherent toxicity while maximizing its antibacterial efficacy. Hydrophobic ionic liquids are non-volatile and non-leaching thus they do not contribute to air pollution nor leach into aqueous environments. In this way, ecotoxicity and acceleration of antibacterial resistance can be minimized. In this study, two hydrophobic ionic liquids, benzalkonium docusate and lidocaine docusate, were evaluated and show excellent antibacterial properties against Gram-positive pathogenic bacteria. Potential enhancement of antibacterial efficacy is possible by tuning the ionic pairing to create "designer" hydrophobic ionic liquids that are highly antibacterial.

INFORMATION AND COMMUNICATIONS TECHNOLOGY

Minimum Energy Control of Arbitrary Size Networks of Linear Systems via Graphon Limits
By Shuang Gao and Professor Peter Caines
To achieve control objectives for extremely complex and very large scale networks using standard methods is a challenging, if not intractable, task. In this paper, we propose a novel way to approximately control network systems which lie in a sequence with a well defined limit by the use of graphon theory and the theory of infinite dimensional systems. The general controllability problem is analyzed for the infinite system and then the control performance in terms of the upper bound for the L2 state error between the limit system and the sequence of network systems is given. Finally, an example of the application of the minimum energy control methodology for network systems with sampled weightings is demonstrated.

Tricone Drill Bit Condition Monitoring
By Rafezi Hamed and Professor Ferri Hassani
As mining industry is moving toward automation, increasing the efficiently and precision in production, a successful drilling condition monitoring is a vital step forward. Drilling and blasting are two preliminary tasks in surface mining and Tricone bits are preferred in most rotary drilling applications for blasthole drilling. Bit health condition affects the drilling performance significantly and the total drilling cost consequently. In addition, determination of the best time to change the bit is a crucial issue. Furthermore, bit failure during the operation will result in subsequent costs for the mining company.

Raising the Heat: Electrical Muscle Stimulation for Simulated Heat Withdrawal Response

By Pascal Fortin and Professor Jeremy Cooperstock

Virtual Reality (VR) has numerous mechanisms for making a virtual scene more compellingly real. Most effort has been focused on visual and audio techniques for immersive environments, although some commercial systems now include crude haptic effects through handheld controllers or haptic suits. We present results from a pilot experiment demonstrating the use of Electrical Muscle Stimulation (EMS) to trick participants into thinking a surface is dangerously hot. This is accomplished by inducing an artificial heat withdrawal reflex by contracting the participant's bicep shortly after contact with the virtual hot surface. Although the effects of multiple experimental confounds need to be quantified in future work, results so far suggest that EMS could potentially be used to modify temperature perception in VR and AR contexts. Such an illusion has applications for VR gaming as well as emergency response and workplace training and simulation.

Expressing Human State via Parameterized Haptic Feedback for Mobile Remote Implicit Communication

By Jeffrey Blum and Professor Jeremy Cooperstock

As part of a mobile remote implicit communication system, we use vibrotactile patterns to convey background information between two people on an ongoing basis. Unlike systems that use memorized tactons (haptic icons), we focus on methods for translating parameters of a user's state (e.g., activity level, distance, physiological state) into dynamically created patterns that summarize the state over a brief time interval. We describe the vibration pattern used in our current user study to summarize a partner's activity, as well as preliminary findings. Further, we propose additional possibilities for enriching the information content.

Wind Generation Auxiliary Control for Stability Enhancement of Power Systems

By Dmitry Rimorov and Professor Geza Joos

Rapid development of renewable generation technology and gradual replacement of conventional energy sources driven by economic, social and environmental incentives puts additional burden on power system operation and planning routines. Several key challenges associated with the integration of renewable generation arise from drastically different behavior of inverter-interfaced generation during disturbances. The focus of this work lies in the analysis and improvement of power system stability with the presence of renewable generation, specifically wind generation as most abundant in the renewable energy mix. Recognizing flexibility of wind generation control capabilities, we develop auxiliary control loops aiming at enhancing several aspects of power system stability and efficient methods of their design and tuning.

Enhancing Microgrid Security and Resilience to Cyber-Attacks using a Fallback Control Approach

By Martine Chlela and Professor Geza Joos

Microgrids exploit local and renewable energy resources to create a sustainable power infrastructure and enhance power supply security and resilience to extreme events. Microgrids are being increasingly deployed to integrate more renewable intermittent generation, conventional distributed generation and storage systems, collectively known as distributed energy resources. This deployment is enabled by recent developments in advanced sensing, monitoring and control, and information and communication systems that provide flexible, reliable and efficient operation of complex systems but create vulnerable access points exploitable by cyber-attackers. A cyber-resilient control infrastructure enhancing the resiliency of islanded microgrids compromised by false data injection and Distributed Denial-of-Service cyber-attacks is proposed. The strategy is tested on a real-time hardware-in-the-loop co-simulation platform and it enables coordination between DERs and loads without relying on vulnerable communications providing transient and steady-state frequency stability, power and energy management, and increasing the grid capacity to host renewable energy and continuously supply critical loads.

A Weighted Point Cloud Matching Method for SLAM

By Duowen Qian and Professor James Forbes

The first step for any robot to achieve autonomy is to create a map of its surroundings and localize itself within this map at the same time. This is known as Simultaneous Localization and Mapping (SLAM). One way for robots to solve the SLAM problem is to use onboard stereo cameras to extract features from a scene and reconstruct a series of point clouds as the robot moves. Then, by matching corresponding point clouds, the relative pose of the robot and landmarks it sees along a path can be obtained. Point cloud matching is traditionally solved using Horn's method but it detrimentally simplifies the point cloud to a centroid, thereby making it impossible to weigh measurement uncertainties. The research at hand presents a novel method to solve the point cloud matching problem while making use of measurement weights and in the process, achieving greater accuracy for navigation and mapping.

SUSTAINABILITY IN ENGINEERING AND DESIGN

Application of Renewable Energy in Mining Operations

By Leyla Amiri and Professor Ferri Hassani

Underground mines have a ready supply of geothermal energy at their depths that is not being utilized at all. The geothermal energy can be recuperated from active mines through a closed loop system (i.e. stope-coupled heat exchanger) and/or through an open loop system (i.e. mine water pumped to surface). Evaluating of utilizing a lake for a cold water source as an alternative to conventional refrigeration plants is the other purpose of this study. It examines the possibility of harnessing the potential hydraulic energy of the cold lake water through the use of turbines, in order to reduce water pressure and produce usable energy.

PERWAVES Combustion Experiment on MAXUS 9

By Jan Palecka and Professor Jeffrey Bergthorson

The use of metal suspensions as clean zero-carbon-emission energy carriers has been a topic of a large body of research. Yet, the combustion of micron-size metallic particles is a complex multi-scale phenomenon and is a result of the interaction of chemical kinetics, transport phenomena, and heat transfer. In order to study well-defined suspensions without particle settling and to eliminate buoyancy-induced disruption of the flame, both caused by gravity, mixtures of iron particles have been ignited in low-diffusivity gases in a microgravity environment aboard the European Space Agency sounding rocket MAXUS-9. The 12-minute testing in weightlessness allowed the observation of the so-called discrete regime of flame propagation in which the flame is independent of the amount of oxidizer in the mixture. The study of this phenomenon, accompanied by a front propagation through percolation (hence the name PERWAVES – PERcolating WAVES) furthers the current understanding of metal combustion.

Quasi-Steady-State Approximation (QSSA) Framework to Reduce Complex Thermochemical Mechanisms

By Antoine Durocher and Professor Jeffrey Bergthorson

The increased use of variety of fuels and fuel blends in the gas turbine engines coupled with the increasingly stringent regulations on emissions require manufacturers to assess how their products perform in different operating conditions. With increasing computational capabilities, large chemical kinetic models have been developed to assess emissions over ranges of conditions. To reduce calculation time while retaining accuracy, the quasi-steady-state approximation (QSSA) is implemented in the commercial CFD solver (Fluent 17.2). The QSSA is applied to a one-dimensional axisymmetric opposed-flow flame using a detailed thermochemical mechanism to study the impact on solution accuracy and computation time for an increasing number of species set to quasi-steady-state. Starting with the full mechanism, species are ranked based on their reaction speeds and gradually removed, significantly reducing computational time while maintaining solution accuracy for key combustion targets.

Are There Nanoplastics in Your Personal Care Products?

By Laura M Hernandez and Professor Nathalie Tufenkji

The occurrence and toxicity of microplastics in the natural environment is well established; however, due to methodological challenges, the presence and impact of nanoplastics (<100 nm) in natural systems have been largely ignored. Microbeads used in consumer products such as scrubs and shampoos are processed by mechanical means that may lead to their fragmentation into potentially more hazardous nanoplastics. In this study, three commercial facial scrubs containing polyethylene microbeads were examined and the presence of polyethylene nanoplastics was confirmed. This work confirms that personal care products can be a source of nanoplastics to the natural environment via domestic wastewaters. Given the potential severity of the health and environmental impacts of nanoplastics, the findings presented here suggest that this smallest fraction of plastics deserves further study and scrutiny by researchers and policy makers.

Effect of Acoustic Noise on Optimal Synchronous Reluctance Machine Design Regions

By Mohammad Hossain Mohammadi and Professor David A. Lowther

This paper investigates the rotor design optimization of synchronous reluctance machines (SynRMs) by using electromagnetic and structural finite element simulations. Three conflicting objectives, i.e. average torque, torque ripple and loudness, were considered using a surrogate-based multi-objective approach. While the stator is fixed, the rotor flux barriers of a 33-slot 8-pole SynRM were geometrically varied to extract optimal design regions. These regions or constraints help decrease the computational time during the sampling procedure of a multiple-barrier design. Different numbers of flux barriers were studied and related to each other. Adding the loudness was observed to affect previous results by spreading the Pareto front solutions across the design space.

Energy Storage via the Power to Gas Process - Development of a CO2 Methanation Unit

By Jose Augusto Hernandez Lalinde and Professor Jan Kopyscinski

Energy storage is required to overcome the intermittency of renewable energy. The Power to Gas (P2G) process converts excess electrical energy into chemical energy via electrolysis, followed by catalytic conversion of H2 with captured CO2 to CH4, which can be stored in the natural gas grid. The catalyzed CO2 methanation reaction is the most important step in the process as the reaction is highly exothermic. Combined catalyst and reactor design are important in order to develop an efficient P2G process. Within this research, we synthesize ordered mesoporous catalysts, study the relationship between catalyst structure and activity, investigate the reaction mechanism and determine the reaction kinetics. The kinetic data are collected by means of a novel optically accessible catalytic plate reactor with spatially-resolved measurement techniques that allows us to gather gas composition and catalyst surface temperature profiles along the reactor axis, which is not possible with traditional lab-scale reactors.

Finite Element Design and Manufacturing of a Nylon-String Guitar Soundboard from Sandwich-Structured Composites

By Negin Abaeian and Professor Larry Lessard

Composites have many potential advantages over wood in the construction of string instruments, including less sensitivity to humidity and temperature, better durability, and uniformity of mechanical properties that can lead to more predictable vibrational behaviour. The aim of this project is to use Finite Element Methods (FEM) to design and manufacture the soundboard of a nylon-string guitar from sandwich-structured composites, and compare its vibrational behaviour with that of a reference wooden one. Experimental modal analysis is then performed on the manufactured soundboard, where its natural frequencies and mode-shapes are determined and compared with those of the reference soundboard. A reasonable agreement is observed between the simulation and the experimental results, and the dissimilarities observed in the vibrational behavior of the wooden and the composite soundboards are discussed.

Analysing Drivers' Value of Travel Time from a Stated-Preference Survey: Contingent Valuation and Discrete Choice Modelling

By Kotaro Sasai and Professor Omid M. Rouhani

Research gap exists in terms of the effective methodologies to estimate value of travel time (VOTT) accurately. This paper studies two common methodologies to estimate VOTT from stated preference surveys, contingent valuation (CV) and discrete choice modelling (DCM). Using the Dallas Greater Area as the case study, the authors conduct a stated-preference survey to examine the results of VOTT estimations when utilizing the two methods. The survey results suggest that CV tends to estimate VOTT lower than that of DCM. CV reports median VOTT at around $5/hr to $10 while DCM provides an estimate of $16/hr for the whole sample. This discrepancy among the methods can become even large when the sample is divided into socio-economic groups. It is then concluded that two methods result in fairly different estimates. The authors recommend to note that this inherent difference within the methods can result in estimation bias.

Cascading Effects of Transverse Failure of a Transmission Tower

By Syed Fiza Edroos and Professor Ghyslaine McClure

Overhead transmission line suspension towers in North America, are prone to wind storms which are a principal cause for dynamic effects. The objective of this study is understanding the consequences of the transverse failure of a support on the adjacent supports and spans. "When a support falls in the transverse direction, its adjacent effective spans become longer and large conductor tensions are induced at the adjacent structures, creating significant transverse and longitudinal load imbalances. If these supports also fail, the collapse may progress, forming a transverse cascade.", as explained in the report, 'Mechanical Security of Overhead Lines, Containing Cascading Failures and Mitigating Their Effects', of the Working Group B2.22. This study has been accomplished in stages mainly to investigate and determine the parameters that can be exploited to maintain the mechanical and structural integrity of the adjacent system in the event of a failure. In this research, non-linear dynamic analysis has been conducted with the commercial finite element software ADINA. 3D models of the tubular tower structure designed for a potential difference of 230kV and the associated spans have been modelled conforming to the engineering design data provided by Hydro Quebec. The computational model has been designed to represent an equivalent line elements system for the tubular tower structure. Post-yield strengthening due to strain hardening of steel has been accounted through a bilinear curve. Multi-linear inelastic material model has been employed to accurately estimate the response of the conductor and ground-wire to the controlled rotational displacement of a support. The unbalanced forces transferred due to a transverse failure are studied under load cases which aim at imitating the failure of a support within short time durations to understand the dominance of inertial forces on the response. These forces are compared with the varying spans precisely, the span lengths associated with the 230kV support, viz., 250m, 300m, 350m and 400m. The parameter governing the transfer of unbalanced forces has been found as the span length and corresponding initial tension for the event considered in this study.

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MIAE is an initiative of the Lorne Trottier Chair in Aerospace Engineering to foster interest in Aerospace Engineering among undergraduate and graduate students and awareness of the multi-disciplinary and multi-cultural environment in which they may work as future engineers working in the Aerospace Industry. Students accepted into the Institute will be given the opportunity to participate in a number of 500 to 1000 hours Research Projects proposed by the Aerospace Companies. The Institute is also creating at McGill a special environment where the students will have access to a secure room with complete computer facilities, so that they will be able to work in their projects with the support of their professors. The MIAE students will also be given the opportunity to participate in other activities, organized to give them a comprehensive view of the Aerospace Industry and its challenges, such as plant visits and specially designed courses.
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MIAM was established by the Faculties of Science and Engineering to act as a focal point for research into all forms of advanced materials. Engineering innovation and materials creation have led to important developments in communications, information technology, transportation, clinical diagnosis and care, and energy generation, for example. New materials are considered by knowledge-based economies to be a precursor to many technological developments necessary for development and growth, and have been identified as one of Canada's strategic areas of research, and a priority area for McGill. http://www.mcgill.ca/miam/

The Centre for Intelligent Machines (CIM) is an inter-departmental inter-faculty research group which was formed in 1985 to facilitate and promote research on intelligent systems. Intelligent systems and machines are capable of adapting their behaviour by sensing and interpreting their environment, making decisions and plans, and then carrying out those plans using physical actions. The mission of CIM is to excel in the field of intelligent systems, stressing basic research, technology development and education. The members of CIM seek to advance the state of knowledge in such domains as robotics, artificial intelligence, computer vision, medical imaging, haptics, systems and control, computer animation and machine and reinforcement learning. http://www.cim.mcgill.ca/

The McGill EngInE, the Faculty of Engineering Innovation and Entrepreneurship hub focuses on stimulating and supporting technologically-based innovation and entrepreneurship at McGill. Its two-fold missions are to help develop the next-generation of McGill technological innovators and entrepreneurs by providing education and advice, funding, and mentorship; and 2) to increase engagement and R&D collaborations between innovation-driven companies and the Faculty of Engineering by providing matching and facilitation services. https://www.mcgill.ca/engineering/initiatives/engine

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