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SPECIAL ISSUE ON

The Future of Transportation

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Editor's Letter

It is with great pleasure that we bring the 2023 spring issue of the Canadian Society for Mechanical Engineering (CSME) *Bulletin*, this time dedicated to the *Future of Transportation*. This topic is of special interest considering worldwide goals to move towards a zero-emission energy system and that most vehicles these days are propelled by greenhouse emitting fossil fuels consuming, in places like Canada, nearly a third of our primary energy. This issue is co-edited with the CSME Technical Committees in Transportation Systems, represented by Drs. **He** and **Minaker**, and Engineering Analysis and Design, represented by Drs. **Usmani** and **Akbarzadeh**.

Before the main topic of the issue, please remember the CSME 2023 Congress will be held at Université de Sherbrooke, Sherbrooke, Québec from May 28 to 31, 2023. We look forward to meeting you there. For this issue, Dr. Masson has provided the CSME *Bulletin* with an introduction to their department. We hope you enjoy the event. The *Transactions* of the CSME (TCSME) is also encouraging authors of abstracts and conference papers to submit extended versions of their presentations to the *TCSME* CSME 2023 special issue. The new *TCSME* open access agreements discussed in the issue are likely to increase their impact and circulation significantly, so please consider contributing to *TCSME*.

The feature articles in this issue cover topics such as vehicle power source selection, improved battery fast-charging, energy supply for light- and heavy-duty vehicles, and advanced materials. Vehicle owners are now faced with a choice between conventional, plug-in hybrid, battery electric and fuel cell vehicles. Dr. **McTaggart-Cowan** shows that, if you aim at minimizing GHG emissions, your vehicle selection might depend on your postal code. Battery electric vehicle sales are increasing exponentially, but their range and fast-charging abilities remind a concern for many customers. Dr. **Xianke Lin** shows us how advanced battery modeling and health-conscious fast charging algorithms are addressing these concerns. Drs. **Ming Zheng** and **Xiao Yu** highlight the problems with the introduction of battery-powered vehicles in heavy-duty vehicles and show how synthetic fuels, such as hydrogen, could reduce emissions in this sector. Electric vehicle deployment will depend on our ability to increase electricity supply to our electrical grid. **John Gorman** highlights how the nuclear energy industry aims at moving towards supporting the electricity grid to meet the increasing demands due to the deployment of electric vehicles via refurbishment of old reactors and deployment of small modular reactors. Finally, Dr. **Akbarzadeh** and doctoral candidate **Hossein Mofatteh** introduce the reader to shellular metamaterials and how they could help future vehicles be lighter and safer by minimizing the effects of an impact.

A new generation of faculty members in Canada are also focusing on developing new materials and technologies for transportation systems. We highlight five of them: Drs. **Audrey Sedal** from McGill University; **Sampada Bodkhe** from Polytechnique Montréal; **Hang Xu** from Concordia University; **Ofelia Jianu** from the University of Windsor; and **Mostafa Yakout** from the University of Alberta. Dr. Sedal's research focuses on new physical models that are suited for soft robot design, actuation and sensing strategies that suit highly deformable robot structures, and frameworks for control that leverage this deformability to make robots nimble and intelligent. These robots can be used in various applications including transportation systems. Dr. Bodkhe works on multi-material smart composites and additive manufacturing to develop adaptive surfaces and reconfigurable structures to increase flight efficiencies by improving the aerodynamic performance of aircrafts according to flight loads. Along the same direction of research, Dr. Xu works on programmable metamaterials with static and dynamic reconfiguration that can be used in aerospace applications to develop actuators like smart wings for aircrafts. When it comes to the energy needed for transportation, Dr. Jianu is working towards advances in thermochemical based hydrogen production methods for our transition toward finding a more sustainable fuel and path to net-zero carbon emissions by 2050. Lastly, Dr. Yakout investigates additive manufacturing of metallic and ceramic multi-functional materials containing rare-earth elements that will offer unique properties for the future of transportation.

ME Research highlights recent developments in vehicle safety such as the development of a database for training autonomous vehicles under wintery conditions and the analysis of unstable and dangerous trailer swerving. In the CSME *History* section, Dr. Altintas walks us through the initial development and progress of the Mechatronics and Manufacturing Engineering Education at The University of British Columbia (UBC).

Finally, the CSME *Student Affairs* committee has been busy trying to increase the number of networking events to contribute to the training of the future engineers and academics in Canada. Dr. **Romanyk** shares with us news of the formation of two CSME student chapters and information about this year's National Design Competition.

The next CSME *Bulletin* issue will discuss complex fluids and microfluidics and will be led by Drs. **Martin Agelin-Chaab** and **Mohsen Akbari**, chairs of the Fluid Mechanics Engineering and Microtechnology and Nanotechnology Technical Committees. Please let the CSME editors know your suggestions for future issues.

We hope you enjoy this issue of the CSME Bulletin!

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Chair and vice-chair of the CSME Technical Committee in Transportation Systems

Drs. **AMAN USMANI** and **HAMID AKBARZADEH**
Chair and vice-chair of the CSME Technical Committee in Engineering Analysis and Design

PHOTO (REZAI): COURTESY OF THE LASSONDE SCHOOL OF ENGINEERING, YORK UNIVERSITY / PHOTO (GALLART): TABITHA GILLMAN

President's Message

Message du présidente

Dear CSME Members,

As we arrive at the midpoint of the year, I am pleased to provide you with an update on the latest developments and initiatives at the CSME. I am thrilled to announce that the 2023 International CSME Congress is just around the corner, featuring over 400 papers and associated meetings that will cover a broad range of topics. I am eagerly looking forward to meeting many of you in person in Sherbrooke, Quebec, and extending a warm welcome to all.

Over the last six months, we have made significant progress in addressing some of the challenges faced by the CSME. This includes dedicating considerable time to reviewing our organizational structure and awards, such as the establishment of CSME medals for graduate students across the country. Additionally, we have reviewed our technical committee (TC) structure, activities, and roles to ensure that we are making the best use of our members' expertise. I am pleased to announce the establishment of a new TC, Solid Mechanics, which will further enhance our organization's capabilities.

I want to express my sincere gratitude to all of our members for their unwavering support and dedication to the CSME. It is your contributions that make our society vibrant and successful, and I am excited to continue working with all of you in the coming months.

Sincerely,

ALEKSANDER CZEKANSKI, PhD, MBA, P.Eng., FCSME, FEIC, FCEEA
CSME *President*
Associate Professor, Mechanical Engineering
Lassonde School of Engineering, York University

Chers membres de la SCGM,

Alors que nous arrivons à la moitié de l'année, je suis heureux de vous informer des derniers développements et initiatives du SCGM. Je suis ravi de vous annoncer que le Congrès International du SCGM 2023 est à nos portes, avec plus de 400 présentations et des rencontres associées couvrant une large gamme de sujets. J'attends avec impatience de rencontrer de nombreux d'entre vous en personne à Sherbrooke, Québec, et de vous souhaiter la bienvenue.

Au cours des six derniers mois, nous avons fait des progrès significatifs pour répondre à certains des défis auxquels est confronté le SCGM. Cela comprend la consacration d'un temps considérable à la révision de notre structure organisationnelle et de nos récompenses, telles que l'établissement de médailles SCGM pour les étudiants diplômés à travers le pays. De plus, nous avons révisé la structure, les activités et les rôles de nos comités techniques (TC) pour nous assurer de tirer le meilleur parti de l'expertise de nos membres. Je suis heureux d'annoncer la création d'un nouveau TC, Mécanique des solides, qui renforcera encore davantage les capacités de notre organisation.

Je tiens à exprimer ma sincère gratitude à tous nos membres pour leur soutien indéfectible et leur dévouement envers le SCGM. Ce sont vos contributions qui rendent notre société dynamique et prospère, et je suis ravi de continuer à travailler avec vous tous dans les mois à venir.

Cordialement,

Aleksander Czekanski, PhD, MBA, PEng, FCSME, FEIC, FCEEA
Président de la SCGM
Professeur agrégé, Génie mécanique
Université York

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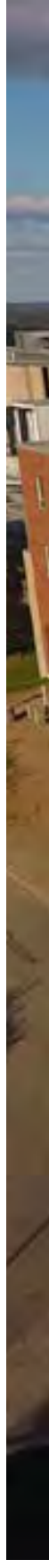

PHOTO: LASSONDE SCHOOL OF ENGINEERING

International Congress 2023

Bienvenue à Sherbrooke!

C'est avec plaisir et honneur que nous vous accueillons à l'Université de Sherbrooke pour cette conférence conjointe de la Société Canadienne de Génie Mécanique (SCGM) et de la société de Dynamique des Fluides Computationnelle (CFDCanada). Nous vous souhaitons une semaine riche en échanges avec vos collègues venus des quatre coins du monde.

La Faculté de génie de l'Université de Sherbrooke occupe une place enviable dans les domaines de la formation et de la recherche appliquée en encourageant la communication et le travail d'équipe. La Faculté est propulsée par une croissance de ses revenus de recherche et s'est positionnée comme la plus intense en termes de recherche partenariale au Canada. Dans ce milieu convivial, la découverte et l'esprit d'initiative sont fortement favorisés. De plus, la Faculté privilégie une formation rigoureuse et complète de ses étudiantes et étudiants et elle est reconnue notamment pour l'alternance études-stages. Par son dynamisme, la Faculté de génie se distingue des autres universités canadiennes en matière de transfert technologique et en termes d'impacts qu'elle a sur la société. Pour favoriser sa croissance à long terme, elle mise sur plusieurs initiatives interdisciplinaires et domaines en émergence.

Pour sa part, le Département de génie mécanique se distingue par des personnes qui œuvrent activement dans les domaines de l'acoustique audible et ultrasonore, de l'aéronautique, de la bioingénierie et de l'ingénierie du sport, de la conception et du développement de produits, de l'efficacité énergétique industrielle, de l'énergie solaire, des matériaux de pointe, de la mécatronique, des dispositifs micro-électro-mécaniques, de la physique des ondes de choc, de la robotique, de la thermofluide et des vibrations. Avec 6 chaires de recherche et des membres du corps professoral reconnus internationalement, le Département dispose d'infrastructures regroupant de nombreux laboratoires de recherche de pointe, y compris des salles anéchoïque et réverbérante couplées, des souffleries, dont une anéchoïque, un ensemble d'équipements pour la caractérisation des matériaux et structures, des échographes de recherche, des plateformes de prototypage de contrôleurs, et plusieurs de ses membres font partie du 3IT, une infrastructure unique pour la micro-fabrication avec 1 600 m² de salles blanches. Le Département se distingue également par son approche de l'enseignement de la conception et par un volet entrepreneurial riche, appuyé par de nombreux partenariats.

Welcome to Sherbrooke !

It is with great pleasure and honor that we welcome you to the Université de Sherbrooke for this joint conference of the Canadian Society of Mechanical Engineering (CSME) and Computational Fluid Dynamics Canada (CFDCanada). We wish you a week rich in exchanges with your colleagues from all over the world.

The Faculty of Engineering of the Université de Sherbrooke occupies an enviable place in the fields of education and applied research by encouraging communication and teamwork. The Faculty is propelled by a growth in research revenues and has positioned itself as the most intense in terms of research partnerships in Canada. In this friendly environment, discovery and initiative are strongly encouraged. In addition, the Faculty favours rigorous and complete training for its students and is known for its alternating studies and internships. Through its dynamism, the Faculty of Engineering distinguishes itself from other Canadian universities in terms of technology transfer and the impact it has Eaon society . To promote its long-term growth, it relies on several interdisciplinary initiatives and emerging fields.

For its part, the Department of Mechanical Engineering is distinguished by people actively working in the fields of audible and ultrasonic acoustics, aeronautics, bioengineering and sports engineering, product design and development, industrial energy efficiency, solar energy, advanced materials, mechatronics, micro-electro-mechanical devices, shock wave physics, robotics, thermofluid and vibrations. With six research chairs and internationally recognized faculty members, the Department has infrastructure with many state-of-the-art research laboratories, including coupled anechoic and reverberant rooms, wind tunnels, including an anechoic one, a set of equipment for characterization of materials and structures, research ultrasound scanners, controller prototyping platforms, and several of its members are part of the 3IT, a unique infrastructure for micro-fabrication with 1,600 m² of clean rooms. The Department is also distinguished by its approach to design education and by a rich entrepreneurial component, supported by numerous partnerships.

DR. PR. MASSON, PhD

Le Pr. Masson est directeur du Département de génie mécanique de l'Université de Sherbrooke depuis 2021. En plus de son rôle administratif, il enseigne la mécatronique et effectue de la recherche en imagerie ultrasonore.

Pr. Masson has served as Chair of the Department of Mechanical Engineering at the Université de Sherbrooke since 2021. In addition to his administrative role, he teaches mechatronics and carries out research in ultrasound imaging.

PHOTOS COURTESY OF THE UNIVERSITÉ DE SHERBROOKE

We are delighted to announce that the CSME 2023 International Congress will be held jointly with the CFDCanada conference on May 28-31, 2023 at the Faculty of Education of Université de Sherbrooke, in Sherbrooke (QC). You can visit the website of the event at www.csmecongress.org.

The congress will open on Sunday, May 28, 2023, with workshops offered during the day and a 5/7 welcome reception. From May 29 to 31, we have organized 5 plenary lectures and numerous technical sessions around 19 symposia : (1) Advanced Energy Systems, (2) Fluid Mechanics Engineering, (3) Heat Transfer, (4) Computational Mechanics, (5) Transportation and Automotive engineering, (6) Biomechanics and Biomedical Engineering, (7) Manufacturing, (8) Materials Technology, (9) Engineering Analysis & Design, (10) Solid Mechanics, (11) Environmental Engineering, (12) Machines and Mechanisms, (13) Mechatronics, Robotics and Controls, (14) Microtechnology and Nanotechnology, (15) EDI Initiatives in Engineering, (16) Energy efficiency in Nordic greenhouses, (17) CFD in the built and urban environment, (18) Hydraulic Turbines and (19) CFD. We have received about 420 abstracts, full papers and workshop proposals submitted to the CSME/CFDCanada 2023 International Congress and all accepted contributions will be included in the program as oral presentations.

On a voluntary basis, all contributions could be extended and published, after a classical review process, in a special issue of the *Transactions* of the CSME. The deadline is the 30 of September, 2023.

The award reception ceremony for CSME, the national design competition and CFDCanada will take place during the banquet at Granada Theater in downtown Sherbrooke, on May 30, 2023.

The CSME and CFDCanada board of directors meetings, CSME General Assembly Meeting, CSME Technical Committee meetings and the Mechanical Engineering chairs and directors meeting will also be held during the congress.

The CSME / CFDCanada 2023 congress is an in-person event, which will take place in the Faculty of Education on the main campus of Université de Sherbrooke (www.csmecongress.org/venue). Attendees with dietary restrictions or those who require special assistance are encouraged to contact us in advance for proper accommodation.

We finally gratefully thank our sponsors and partners (www.csmecongress.org/sponsorship) for their generous support.

The organizing committee,
Professors **Leyla Amiri**, **Hachimi Fellouah**, **Stéphane Moreau** & **Sébastien Poncet**
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Embracing technological diversity on the road to sustainable transportation

DR. GORDON MCTAGGART-COWAN, PhD

McTaggart-Cowan is an Associate Professor in the School of Sustainable Energy Engineering (SEE) at Simon Fraser University (SFU) in Surrey, BC. SEE is a school within SFU's Faculty of Applied Sciences that opened in 2019 in a brand-new building on SFU's Surrey campus. The school offers undergraduate (BASc) and research-focused graduate (MASc, PhD) programs. Gordon joined SEE shortly after it launched and is currently the school's Associate Director. His research is focused on technological solutions to eliminate greenhouse gas emissions from transportation, with a focus on commercial vehicles. His current research projects are focused on supply, handling, and use of alternative gaseous fuels including natural gas and hydrogen, hybrid-electric powertrains and biomass energy conversion. Prior to joining SFU, Gordon spent 10 years at Westport Fuel Systems Inc. as a project and team lead in the Advanced Engineering group, leading applied research projects for high-efficiency low-GHG vehicles. He also spent four years as a Lecturer in the Wolfson school of Mechanical and Manufacturing Engineering at Loughborough University in the UK. Gordon is an associate editor of the Proceedings of the Institution of Mechanical Engineers Part D: Journal of Automobile Engineering. *He has PhD and MASc degrees from the University of British Columbia, and a BEng from the University of Victoria, all in Mechanical Engineering.*

IMAGES COURTESY OF THE RESEARCHER

TRANSPORTATION UNDERPINS MODERN SOCIETY, connecting people and transporting goods across a city or around the world. The vehicles that provide these services consume natural resources, impact local air quality and emit greenhouse gases (GHG). To be sustainable, future transportation systems must minimize these impacts while retaining the societal benefits of low cost and reliable transportation. At the heart of this daunting challenge is ensuring that the propulsion technology that converts stored energy into vehicle motion is efficient and results in low net emissions considering the entire system - from energy source to end use.

Globally, transportation was responsible for 21% of anthropogenic GHGs in 2021. Three quarters of this total was from on-road uses (*Fig. 1*), with about half from light-duty vehicles (cars and light trucks used primarily for personal mobility) and one quarter from commercial vehicles. For most personal vehicles, driving distances are short, use is intermittent, and propulsive power is used primarily to accelerate the vehicle. Commercial vehicles often travel hundreds of kilometers daily carrying payloads that exceed the vehicle's weight. Most propulsive power goes to overcoming drag, rolling resistance and road grade. These differences mean that the most efficient propulsion system for one application may not be appropriate for other uses.

Vehicles with zero local (tailpipe) emissions – such as battery electric (BEV) and Hydrogen fuel cell electric (H_2-FCEV) – are appealing. Quiet and efficient, BEVs made up nearly 7% of global new car sales in 2021, including 13% in China and nearly 10% in Europe (including 65% in Norway). Plug-in hybrids (PHEVs), which combine a limited all-electric range with an internal combustion engine (ICE), made up another 2.5% of new registrations globally and almost 8% in Europe.[3] PHEVs combine relatively small batteries (~1/4 the size of an equivalent BEV's), reducing raw material demand and embedded GHGs. Their electric-only range meets most personal vehicle needs, while their hybrid-electric powertrain enables recovery and reuse of braking energy like in a BEV. Conversely, low-emission commercial vehicles, including BEVs and H2-FCEVs, need to meet demanding daily range, durability and cost expectations. Maximizing payload means space and weight of energy storage are critical: suitable vehicles are still in evaluation or early deployment phases of development.

The attractiveness of zero-emission vehicles and the urgent need to reduce GHGs has led many jurisdictions to announce intentions to restrict sales of new ICE-powered personal vehicles in the next decades. Several vehicle manufacturers have also announced plans to transition to EVs. Commercial vehicle regulations include California's plan to require 40%-75% of new trucks to be zero-emission by 2035. While the intent of these long-horizon regulations are to eliminate GHG emissions from transportation, many are focused entirely on emissions from the vehicle only.

In practice, GHGs may be emitted from energy source to end use. Fuel cycle ('well-to-wheel') analysis quantifies this by combining emissions from energy harvesting and delivery with those from the vehicle. Its outcome depends on local conditions and assumptions: GHGenius has been developed for technology comparison and low-carbon fuel standards (LCFS) to evaluate net GHG emissions from on-road transportation in Canada.

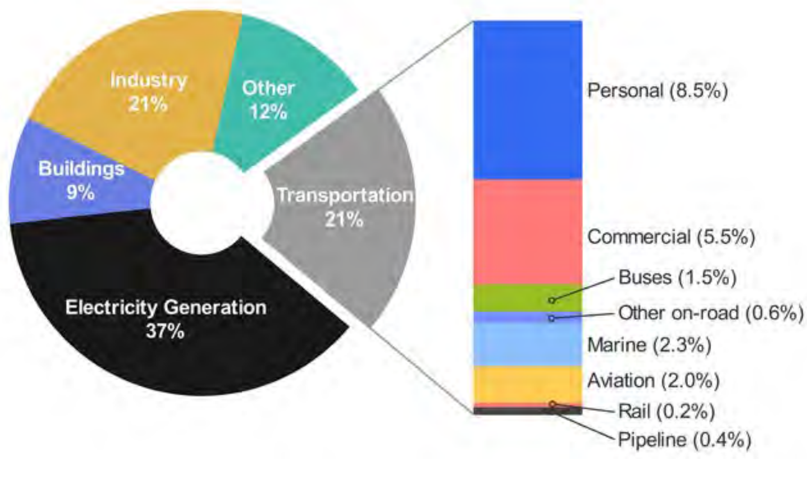

FIG. 1: GLOBAL GREENHOUSE GAS EMISSIONS IN 2021, BY ECONOMIC SECTOR AND DETAILED FOR TRANSPORTATION. BASED ON DATA FROM 1, 2.

Applying GHGenius to personal vehicles in Canada (*Fig. 2*) highlights the challenges and opportunities to reduce GHG emissions. Compared to a conventional ICE-powered vehicle lower-GHG fuels (such as 10% ethanol, E10) and a non-rechargeable hybrid powertrain significantly reduce GHGs. PHEVs and BEVs charged from Canada's clean electricity supply result in even lower GHGs in most regions. If charged from renewable sources, BEVs are near-zero emissions. However, BEV charging is not typically from the cleanest, or even the grid average, source. This marginal increase in electrical demand is normally met by the lowest-cost generator with available capacity. Depending on location, this could be from low-GHG sources, such as hydro, or from high-GHG fossil fuels. Recent estimates for the U.S. suggest that for 40%-60% of the market, marginal electrical supply is disproportionately from high-GHG sources, negating the near-term GHG benefits of BEVs. Globally, fossil-based electrical power (including new coal-fired power stations) remains a substantial contributor to average and marginal electrical supplies in many regions. As electrical demand is expected to grow 75-150% by 2050, high-GHG generation will likely continue to meet marginal increases in demand from BEVs in many regions in the near-term.

Over the past two decades, the efficiency and emissions of ICEs have improved for both passenger and commercial vehicles. Emissions of smog-forming pollutants have been reduced by orders of magnitude, while efficiency standards have led to new technologies that reduce fuel use and GHGs. Investments in R&D, such as the US DOE's SuperTruck programs, have led to many cost-effective improvements. Diesel engines in new large trucks have peak efficiencies of 46-48% with feasible near-term pathways to 55%. Combining high-efficiency ICEs with advances in vehicle and powertrain design, new trucks in 2035 could emit GHG emissions as low as 38 $_{gCO_{2,e}}$/ton-mile: a 50% reduction from a new truck in 2017. While focus has been on the US or Europe, these high efficiency vehicles can be used globally, multiplying the GHG savings from these technological advances.

Further net GHG reductions are possible by combining high-efficiency ICEs with alternative fuels. Biofuels derived from plant waste and algae; e-fuels incorporating captured CO_2; waste-generated renewable natural gas (RNG); and H_2 can all be used as fuels in an ICE to supplement and eventually replace fossil fuels. Some can even achieve negative net GHGs: under California's LCFS accounting, RNG can offset four or more times more GHGs than are emitted from the vehicle by capturing and using instead of venting methane, a potent GHG. These fuels can be blended with conventional fuels for near-term GHG reductions without impairing vehicle performance.

Low-GHG fuels can also be a bridge towards zero GHG transportation. For example, H_2 stations need to be more widely available to enable H_2-FCEVs outside of niche markets. ICEVs that use H_2 would help to drive demand, making H_2 stations economically viable. Using a high-efficiency diesel engine platform, H_2 can be added to the intake air; replacing 30-40% of the diesel fuel and reducing GHG emissions by a similar amount whenever H_2 is available. Advanced ICEs that can use low-GHG fuels while retaining the efficiency and reliability of modern diesels are in development; combining RNG with H_2 could enable near zero net GHG emissions on a well-to-wheel basis.

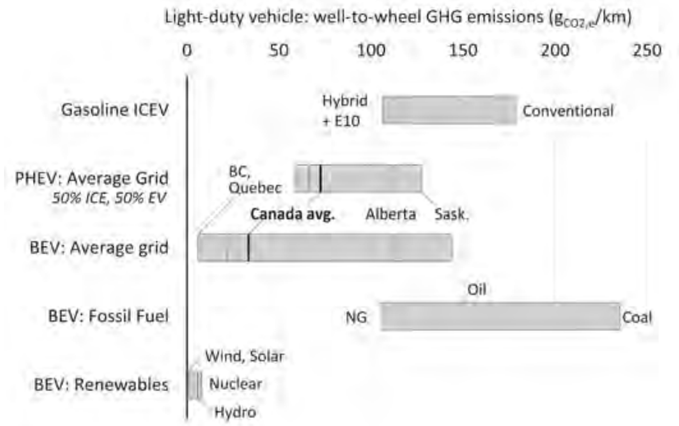

FIG 2: WELL-TO-WHEEL GHG EMISSIONS FOR A CANADIAN LIGHT-DUTY VEHICLE. ICEVS: CONVENTIONAL AND NON-RECHARGEABLE HYBRID-ELECTRIC; PHEVS: GASOLINE AND AVERAGE GRID FOR 50% ALL-ELECTRIC USE; BEVS: AVERAGE GRID, THERMAL POWER GENERATION FROM FOSSIL FUELS, AND SELECTED LOW-GHG/RENEWABLE SOURCES.

The urgent need to address climate change makes it imperative to rapidly reduce GHG emissions from transportation. A vital step is to ensure that the propulsion system and energy supply offer the lowest net GHGs for the region of use and for the application. BEVs are well suited for applications in jurisdictions with ample low-GHG electricity. In regions where marginal electrical supply is from high-GHG sources, FCEVs and high-efficiency ICEVs using low-GHG fuels offer complementary pathways to lower net GHG emissions from transportation. Climate change is a global challenge: having a portfolio of high-efficiency propulsion technologies available is critical to achieving near-term net GHG emission reductions while providing the transportation services upon which modern societies depend.

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BALANCING FAST CHARGING AND BATTERY LONGEVITY

Advances in Battery Modeling and Health-Conscious Fast Charging Algorithms

BATTERY LONGEVITY AND FAST CHARGING

Electric vehicles (EVs) have become increasingly popular in recent years due to their potential to reduce carbon emissions and dependency on fossil fuels. However, the widespread adoption of EVs is dependent on the continuous development of battery technology and fast charging capabilities. Battery cycle life and charging time remain concerning for many potential buyers. It is crucial to study battery degradation mechanisms, build degradation prediction models, and develop fast-charging algorithms that prolong longevity while simultaneously satisfying the requirements of fast charging.

Battery modeling and degradation mechanisms

Battery modeling plays an important role in battery charging algorithm development. Advanced battery models can provide information regarding battery degradation, state of charge, and temperature, which can be used to optimize the battery charging algorithm. Physics-based models will be introduced in this article due to their ability to provide a deeper understanding of battery degradation and aid in the design of fast-charging algorithms that consider the potential battery health implications associated with fast charging.

Physics-based models are based on fundamental electrochemical and thermodynamic principles that govern the operation of the battery. The most well-known physics-based battery models were developed by John Newman's research group at the University of California, Berkeley. In 1975, John Newman applied porous electrode theory to batteries[1], and proposed a mathematical model that describes the behavior of electrochemical batteries in great detail. Later in 1993, the Doyle-Fuller-Newman (DFN) battery model was introduced[2], which is an extension of the Newman battery model. It is widely used in battery research and design for lithium-ion batteries. However, these physics-based models are quite complicated and built upon many partial differential equations, which are problematic for control purposes, such as fast charging algorithms. Battery management systems use embedded controllers with limited processing power, so complex models are often simplified to ensure real-time responsiveness to changing conditions. Therefore, simplified physics-based models called single particle models (SPMs) were developed[3]. The SPM is a one-dimensional model that represents each electrode as one single particle. The main advantage of the SPM is its simplicity and high computational efficiency. All above models do not consider battery degradation. As research efforts increasingly focus on battery cycle life and fast charging, understanding and modeling battery

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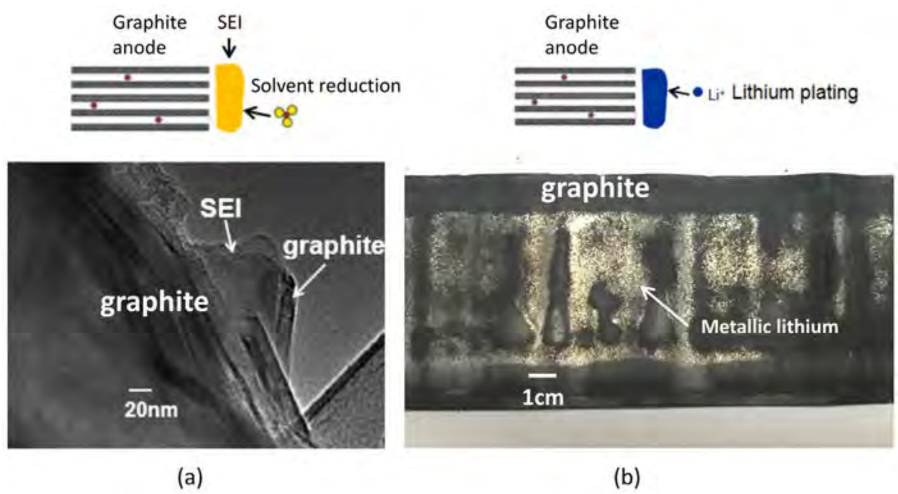

FIG. 1: MAIN DEGRADATION MECHANISMS, A) TEM IMAGE OF SEI ON GRAPHITE ANODE AFTER CYCLING, B) LITHIUM PLATING DURING FAST CHARGING AT 3C RATE.[5]

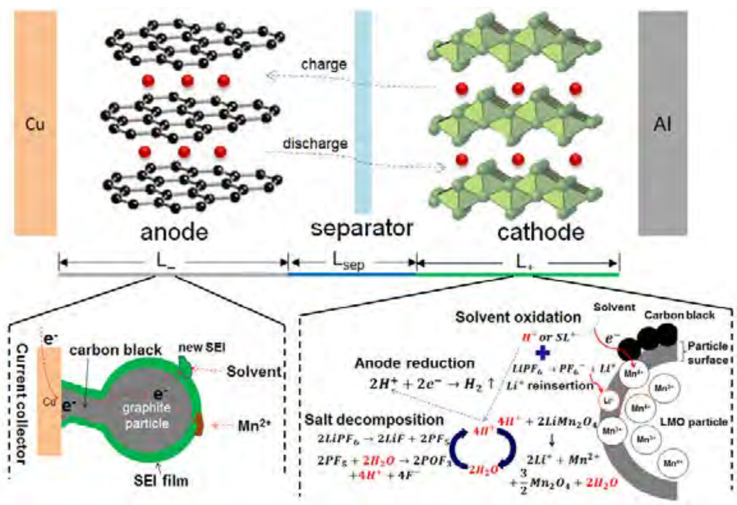

FIGURE 2: A COMPREHENSIVE BATTERY DEGRADATION MODEL.[6]

degradation have become more critical. Several researchers developed models that describe the formation and growth of the SEI (solid electrolyte interphase) layer shown in *Figure 1(a)* in lithium-ion batteries, which is believed to be one of the main degradation mechanisms.[4] Lithium plating is another severe degradation mechanism that is the major problem during the fast charging process[4], as shown in *Figure 1(b)*. Fast charging causes lithium ions in batteries to accumulate on the anode surface, forming metallic lithium (lithium plating) instead of fully intercalating. This metallic lithium can react with the electrolyte, leading to severe capacity fade.

Later, a more comprehensive degradation model[6] was proposed by Dr. Lin, which includes several main degradation mechanisms, as shown in *Figure 2*. The model provides a deep understanding of how each degradation mechanism progresses during long-term cycling. There are several other degradation models developed.[7, 8]

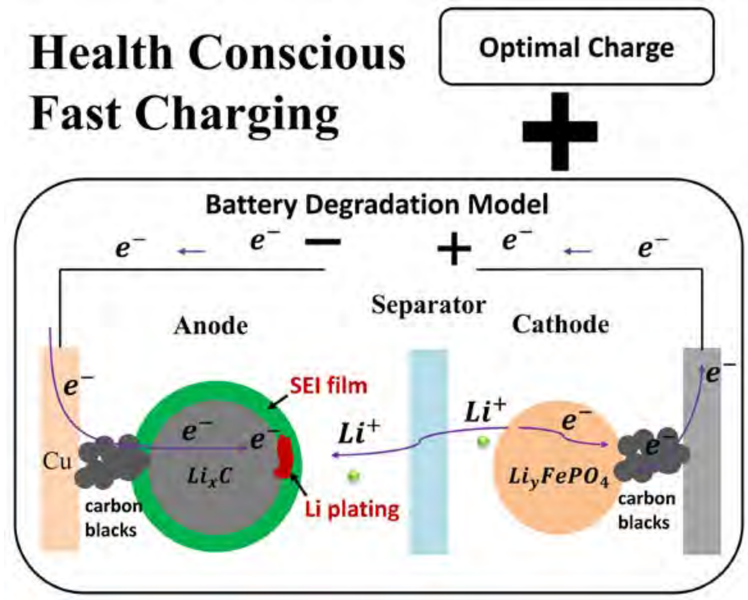

FIG. 3: A HEALTH-CONSCIOUS FAST-CHARGING STRATEGY.[11]

Health-conscious fast charging algorithms

Recent research efforts have focused on developing health-conscious fast-charging algorithms that can balance fast charging with battery life. For example, a study by Yin et al.[9] examined the influence of temperature and current on charging time and battery degradation. They proposed a fast charging algorithm that optimizes the charging current to actively regulate temperature and thereby minimize battery degradation. An alternative approach is to employ empirical equations along with simple equivalent circuit battery models to predict battery degradation. For example, Perez et al.[10] proposed an optimal charging strategy based on an equivalent circuit model with an aging equation. While this approach is straightforward, it lacks the ability to provide detailed insights into battery dynamics and degradation. Another approach is to use battery degradation models to optimize charging strategies. For example, one health-conscious fast charging method developed by Dr. Lin is to optimize the charging current based on the simplified physics-based degradation model[5], as shown in *Figure 3*. This optimized charging strategy divides the charging process into three phases: constant-current / constant-electrolyte-concentration / minimum-lithium-plating. It significantly reduces the lithium plating during the fast charging process while achieving fast charging performance.

Future of battery modeling and fast charging algorithms

Accurate battery models are crucial not only for understanding battery behavior, performance, and degradation but also for designing health-conscious fast charging algorithms. Moving forward, it is important to develop battery models that can predict degradation accurately under different working conditions while maintaining low computational costs. Fast charging generates a lot of heat, which can damage the battery if not properly managed. Therefore, the thermal management system needs to be co-optimized with health-conscious fast charging algorithms. Future research should prioritize developing algorithms that balance the competing demands of fast charging speed and battery longevity while considering the impact of external factors like climate and user behavior. By improving battery modeling and fast charging algorithms, we can enhance the safety, efficiency, and longevity of electric vehicle batteries, and accelerate the transition to a sustainable transportation system.

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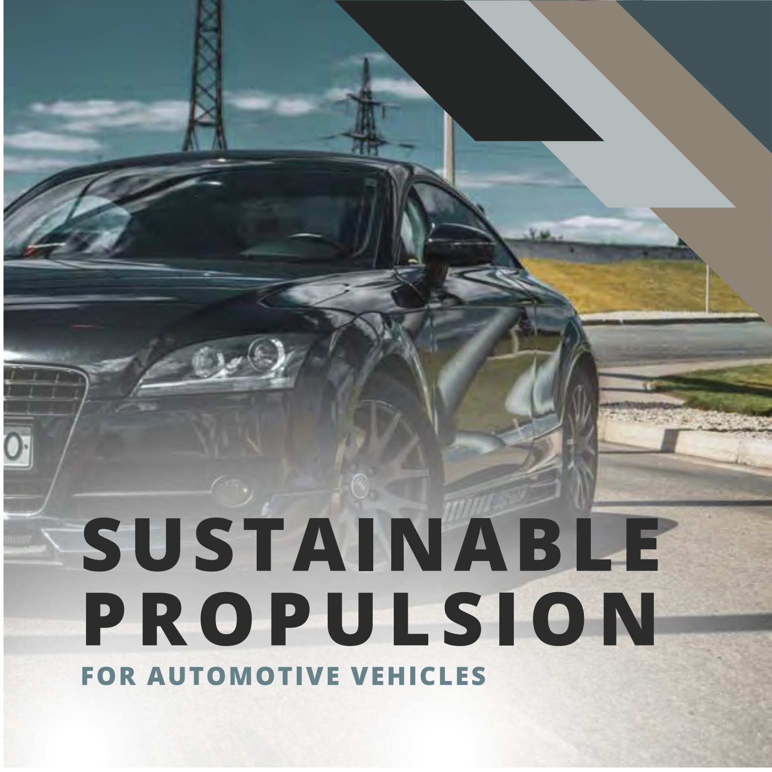

SUSTAINABLE PROPULSION

FOR AUTOMOTIVE VEHICLES

DECARBONIZATION IS ESSENTIAL TO ABATE CLIMATE change. Canada's target is to reduce greenhouse gas (GHG) emissions by 40~45% below 2005 levels by 2030 and get to net-zero GHG emissions by 2050[1], so that the requirements of the Paris Climate Agreement[2] can be met. Presently, thermal energy released during the combustion process provides the majority of the energy demanded by human society.[3,4] However, the burning of fossil fuel releases CO_2 as the main product, which is regarded as the main contributor to the greenhouse effect and climate change.

A rapid adoption of low- to zero-carbon energy sources is needed, together with highly efficient propulsion systems. Among the leading contenders, battery electric vehicles (BEVs) have seen mainstream adoption by the public and demonstrated an unstoppable trend of rapid growth. Governments are setting up policies and fiscal incentives to speed up BEV deployment. Total vehicle registration number of BEVs in Canada have risen significantly in the past three years, with more than 152,000 light-duty BEVs on the road at the end of 2021, accounting for 0.58% of the total vehicle on the road[5]. Heavy-duty electric and hydrogen trucks are also on the horizon, with demonstration units operating around the world. Hydrogen is also a promising energy source to realize zero carbon emission and can be used in both fuel cells and engines, but difficulties in fuel handling and lack of infrastructure remain to be a challenge for its commercialization.

In recent years, electrified powertrains have seen rapid development, providing highly efficient battery-electric drivetrains. Presently, light-duty BEVs are estimated to be 3~4 times more efficient than internal combustion engine (ICE) light-duty passenger cars. Heavy-duty battery electric trucks are 2~3 times more efficient than ICE heavy duty trucks.[6] However, the energy density of a commercialized battery cell is around 40 times lower than that of traditional fuels. Once those cells are assembled into a battery pack, the energy density is further reduced, being 60~80 times lower than traditional fuels.[7]

The relationship between driving range and the energy source weight ratio of various powertrains is shown in *Figure 1*. The ratio is calculated based on the energy source weight and total vehicle weight. Each scatter point represents a commercially available vehicle model, ranging from light-duty passenger vehicles to heavy-duty long hauling freight trucks. For light-to-medium duty applications, the driving ranges of current ICEVs are designed to be around 700 km per full tank. The traveling range of BEVs is around 500~600 km per charge, similar to that of ICEVs. Heavy-duty diesel trucks, on the other hand, can travel more than 3000 km with a full tank. For heavy-duty battery electric trucks, the present traveling range is limited to 500 km.

An “L-shape” pattern is observed, which demonstrates the impact of onboard energy density on traveling range. The two branches of the “L-shape” pattern have distinct slopes from each other, marked as “Slope 1” and “Slope 2” in Figure 1, representing ICEVs and BEVs, respectively. For both light-duty and heavy-duty ICEVs, the fuel weight generally accounts for less than 3% of the total vehicle weight. The high slope of the ICEV branch indicates the minimum amount of extra fuel needed for longer traveling distance.

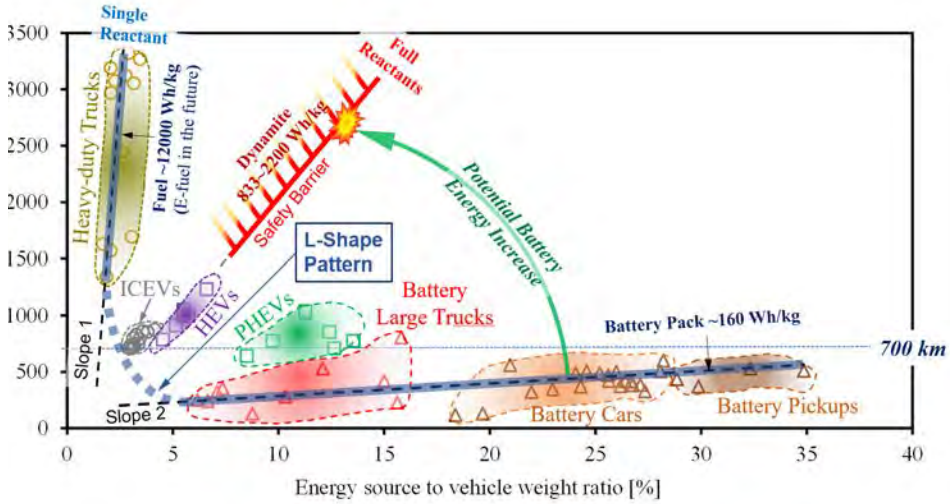

FIG. 1. RELATIONSHIP BETWEEN ENERGY SOURCE TO VEHICLE WEIGHT RATIO AND DRIVING RANGE OF VARIOUS POWERTRAINS. THE ENERGY DENSITY OF DYNAMITE SERVES AS A "SAFETY BARRIER" TO PRACTICAL BATTERIES, BECAUSE BOTH CONTAIN FULL REACTANTS, AND CAN SUSTAIN INTENSE CHEMICAL REACTION (CATCHING FIRE OR EXPLODE) WITHOUT ACCESS TO AIR OR OXYGEN.

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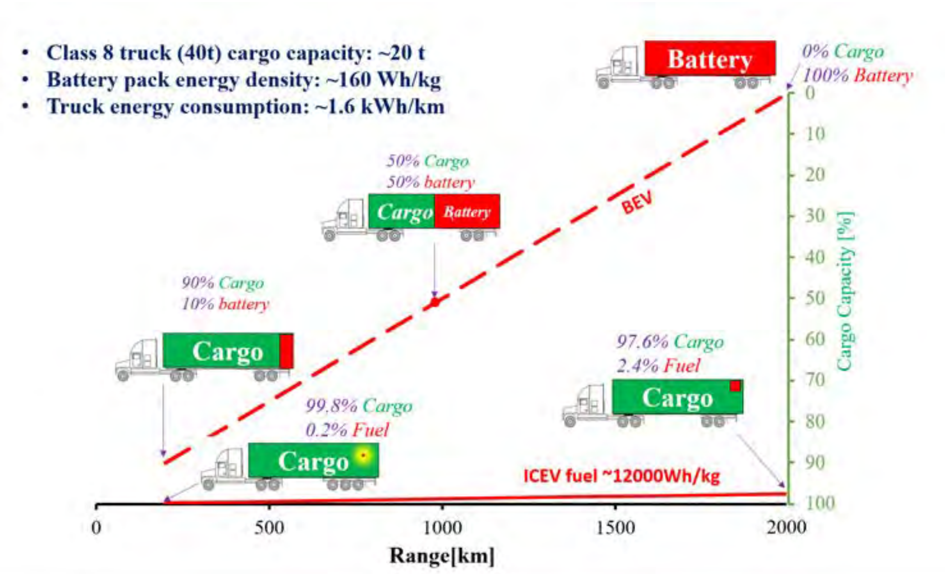

FIG. 2: IMPACT OF ON-BOARD ENERGY DENSITY ON TRAVELING RANGE AND PAYLOAD CAPACITY FOR CLASS-8 TRUCKS.

For light-to-medium duty BEVs, the weight ratio between the battery pack and total vehicle weight ranges from 18~35% for similar traveling distance, because of the energy density of batteries. The impact of the energy source weight on drive range is not apparent when payload is low. Apart from the challenge in fast charging and infrastructure, the light-duty BEVs demonstrate better performance than traditional passenger ICEVs, in terms of less energy consumption, faster acceleration, and lower tail-pipe carbon emissions.

For heavy-duty applications, on the other hand, the energy density of the battery affects the drive range and payload capacity more obviously, because of the much higher energy consumption. A trade-off between cargo capacity and traveling range exists for battery trucks, as shown in *Figure 2*. A typical Class-8 semi truck weighs around 40 tons, with a payload capacity of around 20 tons. With a traveling range of 200 km, the weight of the battery accounts for 10% of the cargo weight. Extending the traveling range to 1000 km will cut the cargo capacity by half. The truck needs to carry more than 20 tons of battery in order to travel 2000 km, leaving zero capacity for cargo.

Presently, Li-ion batteries have the highest energy densities of any commercially available battery technology. The energy density of current commercially available batteries ranges from 155 ~ 260 Wh/kg at the cell level and 125 ~ 200 Wh/kg at the battery pack level[7]. New battery chemistry developments and advanced packaging techniques can further increase the energy density of batteries until it reaches dynamite level, which needs special attention for safety concerns (shown in *Figure 1*). Even at that stage, the energy density of batteries will still be around 15 times lower than hydrocarbon fuels. The fundamental reason is that batteries, just like dynamites, need to carry both reactants to function properly, compared with single-reactant energy sources, such as fuel.[7]

Hybrid vehicles have significantly higher traveling ranges compared with traditional ICE because of the improved fuel efficiency provided by advanced hybrid powertrains, also shown in *Figure 1*. Commercialized hybrid vehicles have been demonstrated to reach fuel consumption below 3L/100km, which have reached similar well-to-wheel energy efficiency compared with BEVs.[8] Furthermore, it should be noted that the ICE is not the root cause of CO_2 emissions, but the fuels that are burnt with it. Low carbon renewable fuels, E-fuels, and non-carbon fuels can be generated from clean energy sources, such as wind and solar, and be utilized in automotive applications[9], including engines and hydrogen fuel cells.

Summary

Sustainable propulsion systems need to meet the demand of various applications, and battery-electric propulsion systems are progressing vigorously, whilst yet confined to the onboard energy density, towards fully replacing traditional powertrains. During the transition period, which might last for decades, highly efficient electric-hybrid propulsion systems and renewable fuels are essential for the decarbonization process and reducing the powertrain impact on climate change.

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CANADA'S NUCLEAR INDUSTRY CAN BACKSTOP THE FUTURE OF TRANSPORTATION

AS COUNTRIES LOOK TO REDUCE THEIR CARBON dioxide emissions in the transition to a net zero economy, two of the first sectors they are looking at are power and transportation. The power sector, because it is both a major source of emissions in most countries and relatively under control of governments or regulated utilities, and the transport sector because consumers have shown a massive and growing appetite for zero emissions vehicles.

However, the decarbonization of these two sectors is taking place unevenly. For example, while the share of electric vehicle (EV) sales in Canada grew from under 1 percent in 2016 to 7 percent in 2022[1], the share of low-carbon power in our electricity system has remained stubbornly at about 80 percent over the past 20 years.[2] This is because while additional low-carbon power sources have been added to the grid, these additions haven't been able to account for both the growth in demand and the decrease in generation due to retirements of coal-fired power generation.

Ensuring that the decarbonization of transport reduces total emissions is going to require the rapid and sustainable decarbonization of our power system – and that means taking advantage of all possible options, including wind, solar, hydro, battery storage, hydrogen, and nuclear. While all these options have strengths, we argue that the decarbonization of transportation would take longer, and be more difficult, without nuclear power.

JOHN GORMAN

John is president & CEO of the Canadian Nuclear Association and past president & CEO of the Canadian Solar Industries Association (CanSIA). John served as Canada's Designate to the International Energy Agency's Executive Committee (PVPS) and was a Founder of the Canadian Council on Renewable Electricity (CanCORE). Before joining CanSIA, he was the Senior VP of Empower Energies, an innovative, global integrator of energy systems. He has served as a director on the boards of numerous community and corporate organizations, including one of the nation's largest electric utilities. John has been recognized as one of Canada's CLEAN50 and is the recipient of the "40 Under 40" business award for excellence in business practices. He was awarded the designation of Climate Project Ambassador by Nobel Laureate Al Gore in 2008.

While trucks, ships, and aviation are likely to rely on biofuels and hydrogen, when it comes to personal mobility, it appears that the future is most likely electric. For example, while hydrogen has the technical potential for personal transport, as of 2022 there were only five hydrogen refueling stations across all of Canada[3] compared to 20,000 public EV charging stations.[4]

This trend toward electrification of transport is being supported by a range of government policies and incentives. The Federal Government has mandated that at least 20 percent of new light-duty vehicles sold in Canada will be zero emission by 2026, at least 60 percent by 2030, and 100 percent by 2035.[5] Many provinces are looking to take advantage of this trend, with Ontario, for example, planning to build at least 400,000 electric and hybrid vehicles by 2030.[6] Additional measures and incentives introduced recently in Federal Budget 2023, including a refundable tax credit intended to drive investment in the manufacturing of EVs and batteries, will accelerate this trend even further.[7]

Some provinces are already moving rapidly toward these targets. British Columbia, for example, reported that almost 20% of all new light-duty vehicle registrations in 2022 were for zero-emission vehicles (at the other end of the spectrum, Saskatchewan's share was just 2.1 percent.)[8]

This shift to electricity for transportation is part of a broader shift toward using electricity in sectors that have, for generations, relied on fossil fuels. Environmental, energy, climate change and government bodies across Canada are exploring the opportunity to electrify large portions of our transportation, buildings, heavy industry, mining, extraction, and manufacturing. However, while electrification of heavy industry is in early days, the electrification of transportation is already underway.

This shift toward electrified transport represents a fundamental change in how Canadians use energy. Today, transportation in Canada accounts for about one quarter of total final energy demand, yet most of this energy is provided by fossil fuels.[9] Shifting to electricity will decrease tailpipe emissions substantially.

It is critically important that the pace of decarbonization of the electricity sector matches the pace of electrification of transport. The alternative is a shift to EVs that does little to reduce Canada's overall greenhouse gas emissions or reliance on fossil fuels.

If Canada meets its forecast targets for light-duty EV penetration by 2050, this could add almost 160 TWh of power demand, equivalent to approximately 25% of total power demand that same year.[10] Realizing this change would require a massive buildout of both electricity generation, and transmission and distribution infrastructure.

Renewable energy, including solar and wind, will continue to play a pivotal role in helping generate clean electricity in Canada. These technologies have made great advances in the past decade to make them more cost effective. But without appropriate long-term energy storage technologies, which are nowhere near being deployed at a rate consistent with a net zero future[11], the contribution of renewables remains limited. Despite rapidly falling costs of wind and solar over the past 10 years, these technologies still only make up around two percent of Canada's total power generation.

Hydro power is a zero-emission option that Canada relies on extensively, yet our country only has a limited number of locations appropriate for damming, which is required to generate this source of energy. The geography must be right, and the extensive amount of land to be flooded cannot be claimed or populated. Even Quebec, which is powered almost entirely by hydro, is facing questions about whether it can meet its own future energy demand growth.[12]

So, while renewables are set to play a meaningful role in Canada's clean energy future, they will need to be complemented by a steady and predictable supply of baseload power to ensure that electrification of transportation (not to mention industry, buildings, and agriculture) doesn't negatively impact grid stability. Development of smart grids and further deployment of battery storage are both potential solutions to this issue, but trends suggest that deployment of EVs is going to outpace deployment of battery storage.

This brings us finally to nuclear power which is, in our opinion, fundamentally important to supporting the electrification of the Canadian economy. Nuclear is emissions-free and delivers predictable and stable power, but more fundamentally than that, Canada's nuclear sector is a strategic asset for our country.

Today, the Canadian nuclear power sector supplies 14 GW of clean, safe, and sustainable power, accounting for 15 percent of the country's total energy output, while generating $6 billion in annual revenue and sustaining more than 76,000 direct and indirect, well-paying jobs.

The industry is currently undertaking a $26 billion refurbishment exercise that will see many of our nuclear reactors generating power until 2060. This process has created thousands of jobs and strengthened an already existing nuclear ecosystem in Canada.

In addition, we are a world-first mover on small modular reactors (SMRs) with the first grid-scale SMR in the G7 set to come online as early as 2028 in Darlington, Ontario. This will have enormous benefits for Canadians, with the global SMR market projected to reach $300 billion per year by 2040. These benefits will almost all be enjoyed by Canadians, as our nuclear supply chain is 95% domestic.

Transitioning to a clean energy future doesn't have to mean energy insecurity. Accelerating the deployment of more nuclear power into our country's power grids will in turn enable us to accelerate electrification – not only of transport, but also industry and agriculture.

The alternative is unlikely to be blackouts; Canada's utilities are well aware of the coming energy crunch. But what is likely is that, in the absence of a further buildout of nuclear power, utilities will continue to burn natural gas to ensure security of supply, or push up electricity rates by overbuilding variable renewables or importing electricity from our neighbours to the south.

The energy transition is underway, and electric vehicles are very soon going to be the new normal for personal transportation in Canada. But ensuring that this shift is good news for emissions and our economy depends on building a sustainable, predictable, and affordable energy mix backstopped by Canadian made nuclear power.

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CANVA STOCK IMAGES (CAR/AWARD)

SHELLULAR METAMATERIALS

A NEXT GENERATION OF COMPACTIBLE, REUSABLE, AND ULTRALIGHT ENERGY ABSORBERS

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Hamid Akbarzadeh, PhD, CRC, MCSME is a Canada Research Chair in Multifunctional Metamaterials, an Associate Professor (Bio-inspired material design) in the Bioresource Engineering Department, an Associate Member (Solid mechanics) in Mechanical Engineering Department, the Director of Advanced Multifunctional and Multiphysics Metamaterials Lab (AM3L) at McGill University, and the recipient of CSME's I.W. Smith Award in 2023. He joined McGill as a Faculty member in 2015 after two and half years of research on architected cellular solids as an NSERC postdoctoral fellow in the Mechanical Engineering Departments at McGill University and the University of New Brunswick. His research and training program at AM3L is aligned with systematic design, multiscale multiphysical modeling, and 3D printing of programmable and smart multifunctional metamaterials and metastructures. To date, his contributions have led to 6 patent applications/reports of invention and 118 published articles in high-impact journals like Advanced Materials, Advanced Functional Materials, Advanced Science, Nature Communications, Energy Storage Materials, and Acta Materialia.

HOSSEIN MOFATTEH, MCSME

Hossein is a PhD Candidate in the Bioresource Engineering Department at McGill University in Montreal, Canada. He joined AM3L at McGill University as a PhD student in 2019 after his MSc and BSc graduation both from Sharif University of Technology in Civil (Structural) Engineering. To date, his contributions have led to 1 patent application and five journal articles in Advanced Materials, Advanced Science, *and* Powder Technology.

Transportation and metamaterials

Transportation is an essential part of modern life, connecting people/places and facilitating the movement of goods/services. Speed, safety, cost efficiency, and environmental impact are all important considerations when choosing a mode of transportation. There is a growing need in society for faster, safer, and more comfortable transportation means. The development of lightweight frames/structures and advanced safety features in electric cars, high-speed trains, and other forms of transportation contributes to achieving this goal and enables reducing the environmental impacts.[1]

Metamaterials, as a class of rationally-designed engineering materials, can offer distinctive and unparalleled properties that are hardly found in naturally occurring materials. A series of lightweight mechanical metamaterials have recently been developed, demonstrating ultra-high stiffness, strength, and energy absorption/dissipation capabilities. These advanced materials can significantly reduce the weight of light-duty vehicles, medium/heavy-duty trucks, aircrafts, trains, and ships as the backbone of transportation, in which weight reduction directly increases speed and decreases energy consumption and greenhouse gas emission. Their high energy absorption/dissipation capability in collision incidents increases the vehicles' safety by protecting humans and goods against impact. At the same time, the reusability of shape-changing metamaterials imparts sustainability in artificial materials. With the rapid emergence of additive manufacturing technologies as robust and low-cost fabrication methods for realizing metamaterials, these high-performance materials will eventually become economic candidates contributing to innovation in smart transportation systems and beyond.

Mechanical metamaterials can be categorized into *extremal, ultra-property*, and *negative* metamaterials[2]. *Extremal metamaterials*, e.g., pentamode and dilatational, have properties that approach the limits of what is physically possible. Pentamode metamaterials demonstrate extremely large bulk-to-shear moduli, while dilatational metamaterials exhibit extremely low bulk-to-shear moduli. These properties make the extremal metamaterials a promising candidate for elastic and acoustic wave guiding[3]. *Ultra-property metamaterials* are a class of materials that surpass the properties of their base materials in terms of stiffness/strength/toughness-to-weight ratios; for example, ceramic nanolattices are strong, lightweight, and recoverable and overcome the brittleness and defect sensitivity shortcomings of the traditional ceramics[4]. *Negative metamaterials* are delicately designed to show properties like negative compressibility or negative incremental stiffness; these materials can protect sensitive devices experiencing impact incidents and can exhibit shape-changing/transformation features. Negative incremental stiffness occurs when a mechanical metamaterial experiences elastic instability, a phenomenon that is harnessed to develop shape-changing bi/multistable materials retaining their deployed/compacted configurations without the need for the exertion of an external load. When a material with negative incremental stiffness is compressed or stretched, the resistive force decreases rather than increases, which can lead to a loss of structural stability (snap-through instability) that causes the material to buckle or collapse. By leveraging this phenomenon, materials/structures can be designed to switch among multiple topology in response to specific stimuli. Multistability in mechanical metamaterials can also trigger snap-back in-

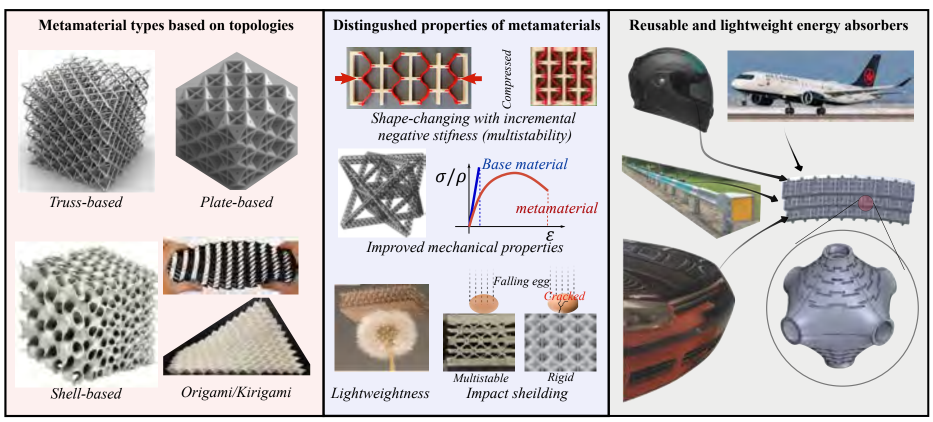

FIG. 1. TYPES OF METAMATERIALS CATEGORIZED BASED ON THE CONSTITUTIVE CELL TOPOLOGY ALONG WITH THEIR DISTINGUISHED PROPERTIES FOR ENHANCING THE FUNCTIONALITIES OF LIGHTWEIGHT PRODUCTS. RECONFIGURABLE, LIGHTWEIGHT, STRONG, AND STIFF MECHANICAL METAMATERIALS WITH HIGH ENERGY ABSORPTION CAPABILITIES CAN BE UTILIZED TO REALIZE REUSABLE PARTS IN ADVANCED TRANSPORTATION MEANS.[7,8–11]

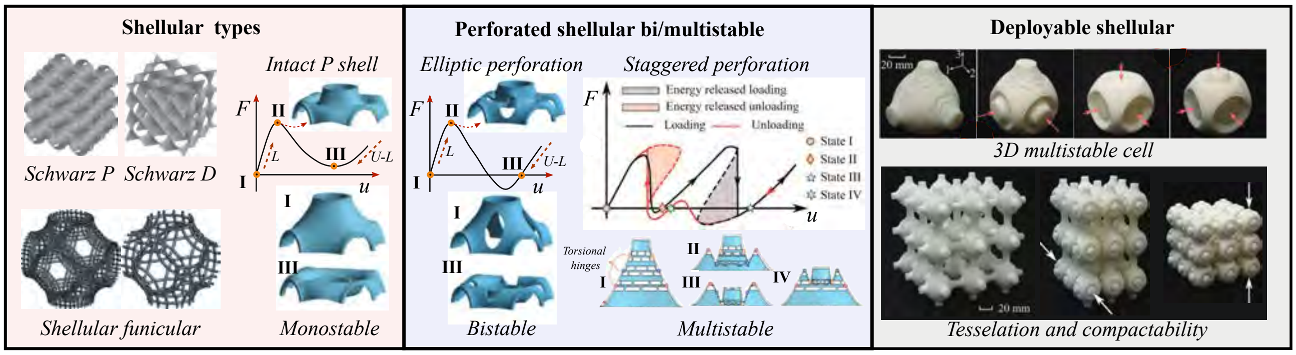

FIG. 2. TYPES OF SHELLULAR MATERIALS AND HOW BI/MULTISTABILITY AND HENCE DEPLOYABILITY/COMPACTIBILITY CAN BE ACHIEVED IN THESE MATERIALS BY INTRODUCING DELICATE PERFORATIONS IN THE CONSTRUCTING UNIT CELLS.[7]

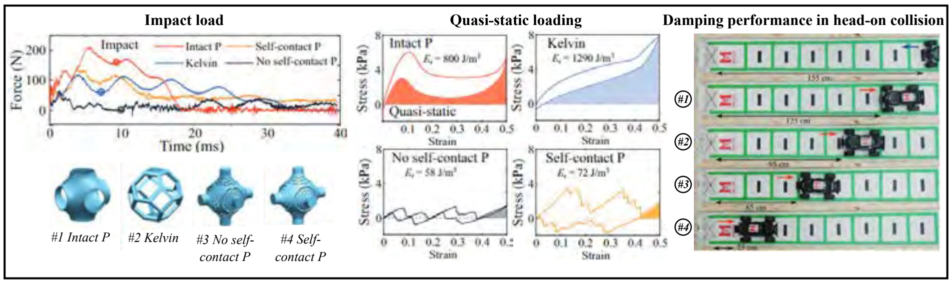

FIG. 3. ENERGY ABSORPTION TRAITS OF SHELLULAR METAMATERIALS UNDER A LOW-VELOCITY IMPACT (DROPPING A 917.8 G MASS FROM 81 MM HEIGHT) AND QUASI-STATIC TESTS. THE LOWEST RETURNED ENERGY AFTER COLLISION BY A MOVING REMOTE CONTROL CAR IS FOUND FOR A PERFORATED SHELLULAR DESIGN WITH A SELF-CONTACT FEATURE.[7]

stability to impart elastic energy dissipation in these architected materials.

While bistability indicates two distinctive and reversible configurations exist in a mechanical metamaterial, multistability refers to the existence of more than two unique stable states.[5,6] Bi/Multistable materials can be compacted and transported in a low-volume configuration and deployed in-situ when needed, making a suitable building block for realizing low-density and deployable structures like reconfigurable solar panels and reflectors mounted on satellites. Concerning the topology of their constitutive unit cell, mechanical metamaterials can be categorized into the *truss, plate, shell, and origami/kirigami*-based metamaterials, each offering a specific range of properties and functionalities (*Figure 1*).[7,8-11]. Among them, shell-based metamaterials have a high surface area in tandem with remarkable stiffness/energy absorption-to-weight ratios and reduced stress concentration, a series of peculiar characteristics desirable for designing architected porous electrodes in high-power micro-batteries and multifunctional energy absorbers.[12]

Perforated shellular metamaterials

A shell-based cellular or Shellular (as a portmanteau word blending of Shell and Cellular) solid commonly comprises a three-dimensional (3D) unit cell of continuously smooth and non-self-intersecting thin shells. These materials are commonly developed based on triply periodic minimal surfaces (TPMS) (e.g., Schwarz P (Primitive), Schwarz D (Diamond), and Gyroid) with zero mean curvature, in which triply periodic refers to 3D periodicity, and minimal surface represents a locally minimum surface area for a given boundary[13]. The *pre-fabricated* topological features of TMPS hold great promise for creating shellular mechanical metamaterials with unparalleled multifunctional properties. The topology of the underlying shell surfaces can also be tailored in the *post-fabrication* state by harnessing the shell's structural instability similar to the instability-driven rapid snapping and fast closure of Venus flytrap in nature.[14] The exquisite functionalities of shellular solids are mainly dictated by the mathematical expressions defining their underlying shell architecture. To broaden their design space, we have introduced perforated shellulars by conformal mapping of delicate perforations on the surface of the primitive shells. These perforations decrease the weight and extend the range of material properties that intact shellular materials attain.[15] Controlling the topology and position of perforations also renders design flexibility to tailor stress distribution within the shellular architecture to engineer its stress-strain curve and structural instability. For instance, we have resorted to elliptical perforations to reduce the resisting bending moment in P shellulars to allow the occurrence of structural bistability caused by harnessing elastic snap-through instability of the perforated shells. Designing layered and staggered perforations imparts bending-torsional hinges, resulting in the development of the multistable kirigami-like shellular metamaterials. The introduced hinges can leverage their self-contact feature to increase these shell-based materials' stiffness/strength and damping performance. With n-layer staggered perforations (n hinges), maximum 2^{n-1} stable states can be achieved in a perforated shellular motif; extending the n-layer staggered perforation in three orthogonal directions results in achieving a shellular unit cell with up to $2^{6(n-1)}$ stable configurations. Tessellated shellular unit cells also demonstrate multistability; the material can be packed to 25% of its volume in the initial unpacked configuration, facilitating its transportability (*Figure 2*).[7]

Metadampers for the next generation of vehicles

Dampers play an important role to dissipate sudden impact loads in transportation vehicles and thus are indispensable for the safe transportation of people and goods, the comfort of passengers, and vehicle performance (e.g., handling). Viscous, viscoelastic, and yield dampers are among the main candidates for energy dissipation. One of the challenges in the yield damper design is controlling the peak of the reflective impact force, which is a primary cause of damage to vehicles, goods, and passengers. Designing lightweight, reusable, and programmable to reduce reflective impact force can improve the safety and efficacy of transportation systems.

We have observed that self-contact and snap-back instability are among programmable energy dissipation mechanisms in multistable shellular metamaterials.[15] Fabricated out of flexible polymers (e.g., thermoplastic polyurethane) using selective laser sintering, these metadampers experience consecutive elastic instabilities, hence reusable, significantly reducing reflective force and vehicle rebound after impact (*Figure 3*). Besides serving as a damper, multifunctional perforated shellular materials can serve as thermal and acoustic insulators, improving the energy efficiency and environmental compatibility of future vehicles.[16,17] In conclusion, to fully capitalize on these mechanical metamaterials in revolutionizing transportation systems, continued research and innovation are necessary to holistically study their durability and multifunctionality and develop low-cost additive manufacturing techniques for mass production. This breakthrough technology in material design has the potential to significantly impact the future of transportation, ushering in a new era of smart, sustainable, and high-performance mobility solutions.

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ME NEWS & RESEARCH

HIGHLIGHTS

FIG. 1: THE AUTONOMOOSE AUTONOMOUS VEHICLE TESTING PLATFORM USED TO COLLECT THE DATASET ON SNOWY WINTER ROADS.

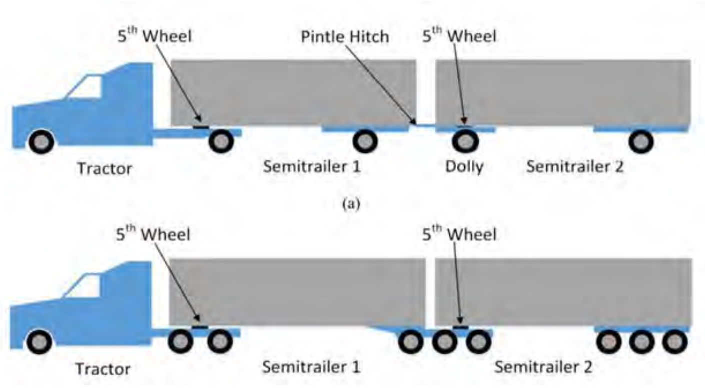

FIG. 2: THE TWO DIFFERENT LCVS CONSIDERED IN THIS STUDY WERE AN A-TRAIN DOUBLE (TOP) AND B-TRAIN DOUBLE (BOTTOM), WHICH DIFFER IN TERMS OF AXLE AND HITCH CONFIGURATIONS.

Improving Autonomous Driving in Adverse Conditions

Anyone who has shopped for a new car lately has likely noticed the incredible amount of driver assistance features, including autonomous driving modes, available on many new vehicles. These features, which cover a range including adaptive cruise control, lane centering, collision avoidance, and even autonomous driving, rely on an array of sensing technologies that provide the vehicle with an understanding of various hazards on the road. What happens, however, when adverse driving conditions such as snowy weather are presented to these systems? How can these systems be trained to work under these conditions? It should come as no surprise that Canadian researchers, who of course are no strangers to these types of driving conditions, have stepped up to offer rich datasets that can help train these systems. The Canadian Adverse Driving Conditions dataset (CADC, pronounced “cad-see”)[1] was recently introduced in the International Journal of Robotics Research by a team of Canadian researchers led by Steve Waslander (University of Toronto) and Krzysztof Czarnecki (University of Waterloo). This multi-modal dataset contains 7,000 frames of annotated data from eight cameras, LiDAR, and a GPS-aided inertial navigation system, mounted on the "Autonomoose" autonomous vehicle testing platform (Fig. 1). The data was collected during 75 driving sequences covering over 20 km of driving in the Waterloo region. Importantly, the dataset includes a wide range of perception challenges, with varying levels of both traffic and snowfall. A subset of the dataset has been annotated, in collaboration with Scale AI (San Francisco) to identify obstacles ranging from pedestrians to snow plows, with plans to release more detailed annotations in the future. To further the development of autonomous driving systems, their dataset is open-source, and can be found online at cadcd.uwaterloo.ca, along with additional details on the project. — *Technical Editor, Prof. Ryan Willing,* MCSME

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Effective approaches for assessing instability of long combination vehicles

When towing a trailer, it is sometimes possible for the trailer to swerve, sometimes repeatedly and with increasing amplitudes until there is a complete loss of control. There are various strategies to mitigate this behavior, including optimizing how load is distributed, the hitch design, and tow-vehicle mitigation systems (active sway control). This behavior can become exaggerated and more complicated to predict for long combination vehicles (LCVs). LCVs are those semi-trucks which are pulling not just one, but two trailers behind them. Depending on the configuration, a lateral disturbance of the tow vehicle can be amplified in the towed trailers; known as rearward amplification (RA), which can be assessed in both the time (RAt) and frequency (RAf) domains. Assessing the dynamic stability and RAs of these vehicles is challenging due to driver-tractor-trailers-road interactions, and different assessment methods result in different and conflicting RA measurements. In their recent paper entitled “On dynamic stability evaluation methods for long combination vehicles”[2], **Yuping He** and his team at University of Ontario Institute of Technology aimed at understanding what the root causes for these disparities are. Their study employed computer models, using a software tool called TruckSim (Applied Intuition, inc., Mountain View, California) to predict the transient responses and RAs of two different LCVs (A-train double versus B-train double) which have different axle and hitch configurations (*Fig. 2*), during different standardized instability tests. Based on their detailed parametric analyses, they have been able to select which tests are the most useful, and future work will include real vehicle experiments on a proving ground with a steering machine following prescribed inputs, as well as driver-in-the-loop field tests and simulations. — *Technical Editor, Prof. Ryan Willing,* MCSME

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News from the *Transactions* of the Canadian Society for Mechanical Engineering (TCSME)

New Open Access Agreements

TCSME is pleased to share that its publisher, Canadian Science Publishing (CSP), has recently signed three new open access agreements, which took effect January 2023. Open access is a key aspect of CSP's upcoming strategic plan and is top of mind as the scholarly publishing industry transitions to an open access future.

Building on CSP's long-term partnership with the Canadian Research Knowledge Network (CRKN), we have established a "made in Canada" open access agreement which enables corresponding authors from CRKN-affiliated universities to publish free and unlimited open access in TCSME. Read more about this agreement here:
https://cdnsciencepub.com/do/10.1139/news.2023.01.30/full.

Two new international agreements have also been secured by partnering with ETH Zurich as well as the University of Oslo on read and publish agreements. For both agreements, corresponding authors from ETH Zurich and University of Oslo (including Oslo University Hospital) receive free unlimited open access publishing in TCSME. All three agreements are considered pilots and will run over a three-year period from 2023–2025, inclusive.

We are hopeful that these agreements will bring new opportunities for growth, increase the visibility and accessibility of research published in *TCSME*, and benefit our authors and research community.

CSME-CFD Canada Congress 2023 Special Issue: Call for Papers

This year's CSME Congress will be held in-person from May 28–31 at Université de Sherbrooke (UdS), Sherbrooke, Quebec, in partnership with the Computational Fluid Dynamics Society of Canada. Authors of abstracts and conference papers are invited to submit extended versions of their presentations to the CSME 2023 Special Issue published by *TCSME*. The Special Issue will be guest edited by Professors **Leyla Amiri**, **Hachimi Fellouah**, **Stéphane Moreau** and **Sébastien Poncet**.

Submission deadline for manuscripts: September 30, 2023.

Please visit the following links for more information on the journal (https://cdnsciencepub.com/journal/tcsme/about), author guidelines (https://cdnsciencepub.com/journal/tcsme/authors#guidelines), and manuscript submission:
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Editor-in-Chief, TCSME
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McGill University
Dr. Audrey A. Sedal

Engineering Frameworks for Soft, Safe, Collaborative Robots

FIG. 1: SOFT, INFLATABLE ROBOTIC ACTUATORS THAT MORPH TO PRE-DEFINED SHAPES WHEN INTERNALLY PRESSURIZED[3]. THE DIMENSIONS OF THE BEAM

Robots are already transforming our lives. In the previous CSME *Bulletin*, Dr. Melek notes that robotics adoption is growing in our post-COVID world; not only in industry, but also through accelerated efforts to develop service and personal robots. Widespread deployment of collaborative robots could improve medical care (e.g., by enabling minimally invasive surgeries), improve quality of life (e.g., by performing arduous home chores), and enable independence by automating difficult tasks of daily living. Compliant-bodied or 'soft' robots have shown potential in all of these areas: introducing this softness allows for lighter-weight robots that naturally deflect around obstacles and clutter while posing less of a safety risk than rigid robot arms. Promising soft robot prototypes have been developed for agriculture, manufacturing, in-home assistance, and medical applications.

Yet, relatively few soft robots can be found in real life. Challenges relating to complex material physics, power density of soft actuators, and a lack of suitable control frameworks make it difficult to engineer robots that function reliably in our changing, living and growing environments. As director of the MACRObotics (Materials, Actuation and Control for RObotics) research group[1], Dr. Sedal investigates how these challenges might be overcome. Her research develops new physical models that are suited for soft robot design, actuation and sensing strategies that suit these highly deformable robot structures, and frameworks for control that leverage this deformability to make robots nimble and intelligent.

Key physical phenomena such as nonlinear elasticity, plasticity and viscoelasticity affect soft robot movements. While a traditional robot can be fully described in terms of the motion of its joints, a soft robot's shape is continuously deformable and sensitive to many possible environmental changes. Research done by Prof. Sedal and her team addresses these changes by modelling the effect of these physical phenomena on robots. Comparison with simplified models shows that nonlinear phenomena affect soft robotic behaviour[2]. Using mechanical models, engineers can find ways to leverage them into designs with mechanically programmable deformation. One example design is given in *Fig. 1*. Here, a meta-material with tunable nonlinear elasticity and negative Poisson's ratio (auxetic) enables design of actuators that morph to curved or non-constant radius shapes[3].

Ongoing work by Prof. Sedal and her collaborators[4] shows how these ideas can be combined into a single framework. We use a high-fidelity dynamic physical simulation with a novel reinforcement learning-based framework that searches across the combined space of soft robot designs and open-loop controllers. As a result, we found a soft robot that crawls faster than an expert-developed baseline and has strong sim-to-real transfer. *Fig. 2* shows some example frames, demonstrating sim-real agreement and the emergence of a novel 3-legged crawling gait.

The MACRObotics group's goal is to develop a suite of well-validated, easy-to-use engineering tools that can help soft robots move out of the laboratory and into real life as collaborators, co-explorers, and assistive devices. We plan to continue developing mechanical models of these complex soft-bodied structures while discovering ways to integrate them with sensing and control.

Dr. AUDREY A. SEDAL, PhD

Sedal is an Assistant Professor at McGill University and leads the MACRObotics (Materials, Actuation, Control for Robotics) group. From 2020-2021, she was a Research Assistant Professor at Toyota Technological Insititute – Chicago. She earned her PhD in Mechanical Engineering at U. Michigan in 2020 and her SB in Mechanical Engineering at MIT in 2015. In 2019, she was named a US Rising Star in Mechanical Engineering.

IMAGES COURTESY OF THE RESEARCHER

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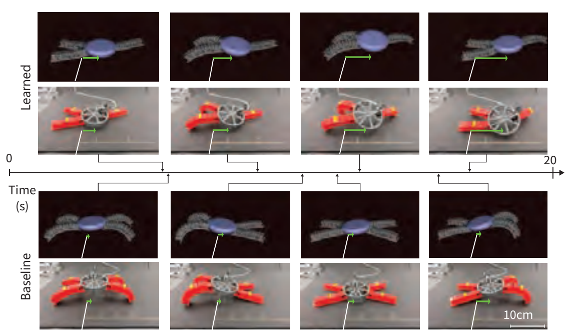

ABOVE TIME LINE: SOFT, CRAWLING ROBOT DEVELOPED WITH DESIGN-CONTROL REINFORCEMENT LEARNING AND CONTINUUM MECHANICS-BASED SIMULATION (TOP ROW) AND A PHYSICAL EXPERIMENT (2ND ROW). THIS ROBOT CRAWLS MORE THAN TWICE AS FAST AS AN EXPERT-DEVELOPED BASELINE. BELOW TIME LINE: EXPERT-DEVELOPED BASELINE ROBOT (SIMULATION: TOP ROW, PHYSICAL EXPERIMENT: 2ND ROW). ADAPTED FROM[4] WITH PERMISSION.

Polytechnique Montréal
Dr. Sampada Bodkhe

Multi-material Additive Manufacturing of Reconfigurable Structures

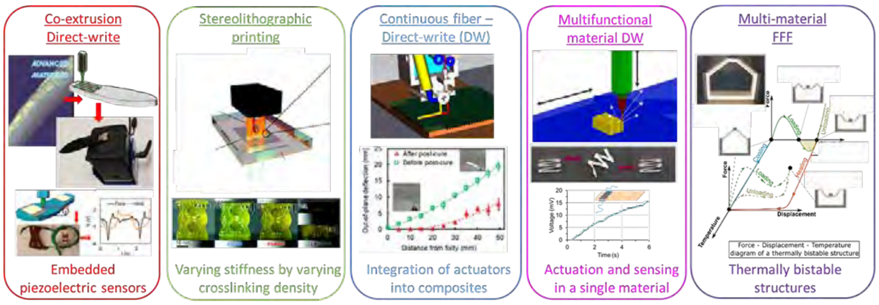

FIG. 1. MULTI-MATERIAL ADDITIVE MANUFACTURING OF SMART STRUCTURES IN THE LABORATORY FOR INTELLIGENT STRUCTURES FROM 5-10.

Dr. SAMPADA BODKHE, PhD

Bodkhe is an Assistant Professor in the Department of Mechanical Engineering at Polytechnique Montreal and the Director of Laboratory for Intelligent Structures. Dr. Bodkhe received her PhD from Polytechnique Montreal in 2017, where she developed piezoelectric inks and a technique to co-fabricate electrodes with piezoelectric sensors via co-extrusion-based 3D direct-write technique. The research on the development of these self-powered sensors towards aero-elastic and biomedical applications was chosen as one of the 10 Best Discoveries of the Year 2018 by Quebec Science Magazine. As a visiting PhD student at the Organic Robotics Laboratory, Cornell University, she worked on SLA based 3D printing of highly flexible actuators. After her PhD, she worked as a Post-doctoral Researcher at Composite Materials and Adaptive Systems Laboratory at ETH Zurich, on establishing competencies in 3D printing of adaptive systems, multifunctional materials and structures. Prior to her PhD, she worked as an Edison Engineer at General Electric Aviation, India on structural and thermal evaluation of components for LEAP 1B engines. She holds a Master's degree in Aerospace Engineering from Indian Institute of Technology Kanpur, India. She has keen interests in building an additive manufacturing platform for the fabrication of intelligent composite structures. She is also an ambassador for the Montreal Chapter of Women in 3D Printing and serves on the advisory board of Indian Women in 3D Printing.

One of the approaches to reduce emissions and fuel consumption in aircraft is to increase flight efficiencies by improving the aerodynamic performance of aircraft by creating surfaces that adapt to flight loads. Adaptive surfaces are estimated to reduce fossil fuel consumption by more than 12% and noise emissions by 40% per flight.[1-3] Adaptation involves detecting a change in the environment through sensors and then employing actuators to respond to this change by modifying the shape of aircraft components, e.g., altering the wing shape, deploying the landing gears, or moving the control surfaces.[4] However, the main challenge in shape adaptation continues to be the non-existence of engineering materials that satisfy all three requirements of mechanical rigidity, reconfigurability, and low weight. At the Laboratory for Intelligent Structures, Dr. Bodkhe's research team works towards sustainable solutions for the fabrication of adaptive smart composites. For example, in creating lightweight, complex-shaped, aerodynamically efficient adaptive control surfaces for aircraft or lightweight conformal smart prosthetic components. The focus is on solving two pressing problems in the manufacturing of smart composite structures: 1. the reduction in mechanical properties upon addition of smart materials into composites, and 2. the large amount of material waste during the fabrication of complex-shaped composite parts through conventional techniques. Dr. Bodkhe develops and applies multimaterial additive manufacturing (AM) techniques for polymer-based materials, through fused filament fabrication, direct-ink write, and stereolithography, to integrate smart functional materials into structural materials.

Dr. Bodkhe's interest for smart materials sparked during her Master's thesis, while developing sensors for the structural health monitoring (SHM) of flapping-wings of micro-air-vehicles. The challenges in the compatibility between the sensors glued to the flapping wing motivated her towards a PhD in developing techniques to coextrude the piezoelectric sensors. In this case, a piezoelectric nanocomposite is sandwiched between two layers of a conducting silver paste as electrodes to harness and transfer the generated charges[5] and coextruded. Direct printing of these coextruded sensors on substrates increases their electro-mechanical response by overcoming the losses from bonding agents, making them an excellent choice as sensors where weight and flexibility are paramount. When woven in the form of filaments into fabrics, these piezo sensors overcome replacement and recharging issues paving the way for motion and vitals' sensing in battery-free wearables. This patented innovation was recognized as one of the 10 best discoveries by the *Québec Science Magazine* in 2018. MSc students in the group are now applying these piezoelectric sensors for continuous monitoring of blood pressures in patients with chronic cardiac issues.

Once, there were sensors that could detect deformation and damages in structures, the next step was to integrate actuators to reconfigure these structures to the environmental changes. During her post-doc at ETH Zurich, Dr. Bodkhe designed a novel AM technique to automate the integration of shape memory alloy (SMA) actuators into polymers and composite materials at room temperature.[7] This technique opens up ways to embed various functional and reinforcing fibers into complex-shaped composites structures. These responsive-active structures for reconfigurable sensors or self-monitoring actuators are essential in the field of remote sensing, adding the necessary signal for closed loop feedback, especially when actuating elements are remotely located inside a human body, in pipelines, underwater, or in outer space.

The above-mentioned actuation strategies result in gradual deployment of structures, whereas, certain applications like bistable transistors, switching elements, etc. require instantaneous actuation. A collaborative project with Prof. Akbarzadeh at McGill University and Prof. Therriault at Polytechnique Montreal, was carried out to design and fabricate novel multi-material structures that exploit the difference in the coefficients of thermal expansion of any two given polymers to achieve instantaneous deflection[9]. These structures can be programmed to actuate between multiple independent stable configurations through temperature changes in the environment.

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Concordia University
Dr. Hang Xu

Programmable Metamaterials with Static and Dynamic Reconfiguration

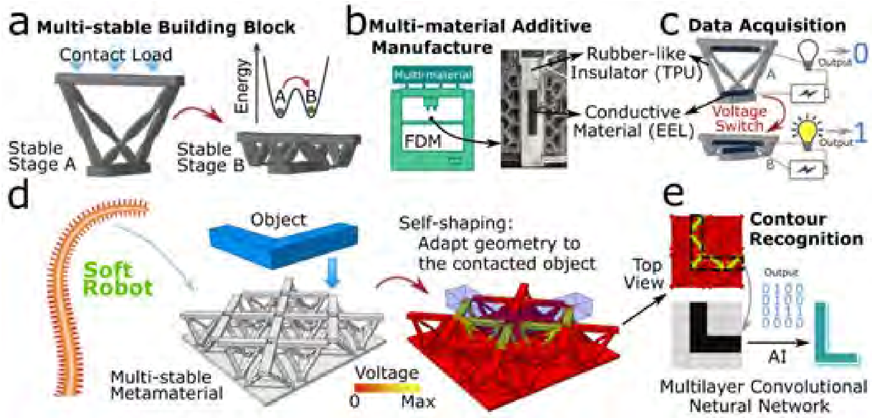


FIG. 1: WORKFLOW OF METAMATERIALS FOR CONTOUR RECOGNITION VIA AI ALGORITHM.

Materials in nature achieve extraordinary properties through their complex architectures. Inspired by nature, scientists are developing artificial composites with complex structures called metamaterials, which obtain their effective properties mainly by structure rather than material composition. Morphable metamaterials, in particular, change their shapes in response to environmental changes. They are thus in high demand for various applications that need to move or deform, such as deployable structures, sensors, and actuators. Dr. Xu and his research team are primarily interested in improving metamaterial morphing functions by a rational structural design. The knowledge gained from this work is then used to develop programmable metamaterials with static and dynamic reconfigurations. Precision-controlled deformation will support a wide range of medical and aerospace applications, such as balloon catheters, soft robots with contour recognition, thermally induced actuators, and deformable smart wings.

Dr. HANG XU, PhD, AFHEA

Xu is an Assistant Professor in the Department of Mechanical, Industrial and Aerospace Engineering at Concordia University. He received his PhD from McGill University and then worked at Siemens as a Mitacs Postdoctoral Fellow. Before joining Concordia, he developed 3D-printable Meta-materials at the Imperial College London. Dr. Xu's research focuses on developing lightweight structures and mechanical meta-materials, multi-material additive manufacturing, and multi-scale mechanics of materials.

During his PhD, Dr. Xu developed lightweight and multifunctional metamaterials with programmable thermal deformation. The developed structurally efficient metamaterials with near-zero thermal expansion can be engineered for aerospace structures (e.g., satellite antenna and precision instruments) to avoid undesired thermal distortion and stress concentration in extreme environments. He developed routes to program thermal expansion/actuation in metamaterials with structural hierarchy. This work was the first to amplify, decouple, and individually tune different functions in distinct hierarchical orders (see for example: J. *Mech. Phys. Solids*, Vol. 117, pp. 54-87, 2018 and Acta Materialia, Vol. 134, pp. 155-166, 2017).

Dr. Xu's team now develops metamaterials with morphing functionalities by mimicking the snap-through mechanism of flytrap multi-stable structures. Multi-stable metamaterials can switch reversibly among multiple stable stages via snap-through buckling caused by mechanical loading (*Fig. 1a*). Distinct stable configurations represent the difference in the contours of contacted objects. Additive manufactured via electrically conductive materials (e.g., NinjaTek EEL in *Fig. 1b*), the unit cells' local snap-through mutates partial voltage via deformation-induced circuit closure (*Fig. 1c*). Through recording voltage changes in each unit cell, different shape reconfiguration extracted by contacting diverse target objects can be recognized and saved as a digital database (*Fig. 1d*). Analyzing the relationship between the deformed stable configurations and object contours via artificial intelligence (AI) algorithm (*Fig. 1e*), adaptive multi-stable metamaterials can be engineered to perform contour recognition.

In aerospace transportation, application-oriented research spans deployable mechanisms and smart wings where deformation or actuation should be carefully managed. The developed multi-stable metamaterial can reversibly switch between different wing shapes and airfoils. Assembled from morphable metamaterials (*Fig. 2*), smart wings can change camber to control the airplane's flight and significantly boost aircraft lift production, control, and maintenance efficiency. Due to the high structural efficiency of metamaterials, the smart wing could enable lighter and more energy-efficient aircraft designs. There are both economic and societal benefits from the outcome of the research, such as reducing costs and greenhouse gas emissions.

In the future, the Advanced Metamaterials and Manufacturing (AMM) Laboratory, led by Dr. Xu at Concordia University, will develop advanced metamaterials and technology with unprecedented properties and functionalities, particularly for aerospace structures and mechanisms, deep-space explorations, soft robotics, and medical devices.

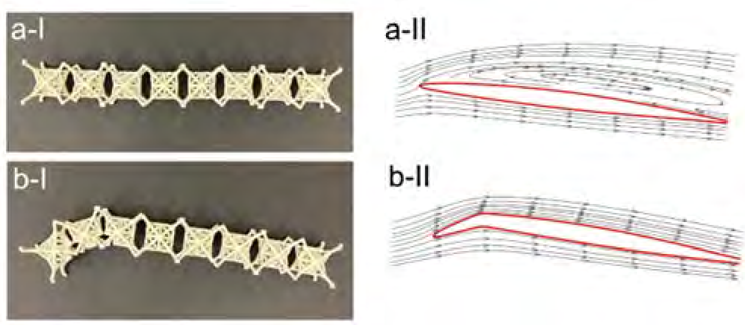
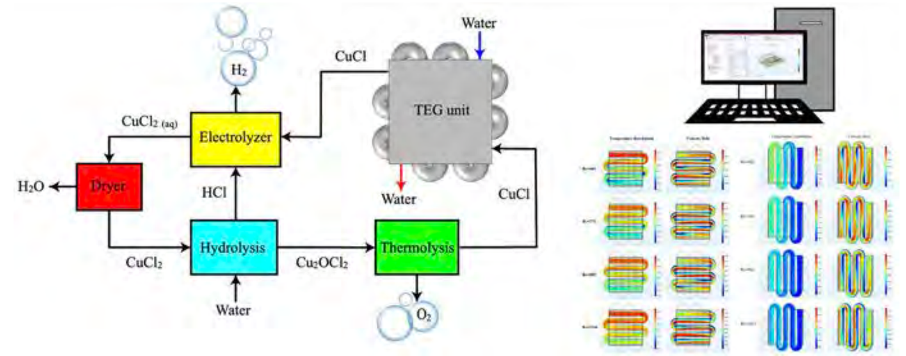


FIG. 2: MORPHABLE METAMATERIALS FOR SMART WING DEVELOPMENT.

University of Windsor
Dr. Ofelia Jianu

Advances in Hydrogen Production Methods for a Hydrogen-based Economy



Step	Chemical Reaction	Temperature Range
Electrolyzer	$2CuCl(aq) + 2HCl(aq) + 32.4H_2O(l) + V \rightarrow 2CuCl_2(aq) + 32.4H_2O(l) + H_2(g)$	343-363 K
Dryer	$2CuCl_2(aq) + 32.4H_2O(l) + Q \rightarrow 2CuCl_2(s) + 32.4H_2O(g)$	333-353 K
Hydrolysis	$2CuCl_2(s) + H_2O(g) + Q \rightarrow CuOCuCl_2(s) + 2HCl(g)$	648K
Thermolysis	$CuOCuCl_2(s) + Q \rightarrow 2CuCl(l) + \frac{1}{2}O_2(g)$	723K-803K

FIG. 1. IMPLEMENTATION OF THE TEG IN THE THERMOCHEMICAL CU-CL CYCLE FOR HYDROGEN PRODUCTION AND 1. MOHAMMADI, AMIR; JIANU, OFELIA A. (2023). NOVEL TEG HEAT EXCHANGER FOR INDIRECT HEAT RECOVERY FROM MOLTEN CUCL IN THE THERMOCHEMICAL CU-CL CYCLE OF HYDROGEN PRODUCTION. *INTERNATIONAL JOURNAL OF HYDROGEN ENERGY*, 48 (13), 5001-5017.

Dr. OFELIA A. JIANU, PhD

Jianu is an Associate Professor of Mechanical Engineering at the University of Windsor in the Department of Mechanical, Automotive, and Materials Engineering. Her area of expertise is in heat, mass and momentum transport with application to alternative fuels and energy conversion systems. The unique feature of Dr. Jianu's research is that she applies the 2nd Law of Thermodynamics to identify losses within the systems and generates solutions to minimize the losses. She has over 40 publications in reputable journals and conference papers in the subject. She is the recipient of the Canadian Foundation for Innovation John R. Evans Leader's Fund, NSERC Alliance International, NSERC Alliance Mission amongst many other research grants. Dr. Jianu and her team continue to investigate phase transitions and transport phenomena with the goal of identifying local irreversibilities, which are detrimental to the performance of sustainable energy systems. The research in I-FuEL benefits Canada's efforts in reducing greenhouse gas emissions and supports economic growth of clean technology leading to the creation of new jobs, economic incentives for new investment and commercialization opportunities in the clean energy sector.

Global warming as an existential threat necessitates mitigation of greenhouse gas emissions due to consumption of fossil fuels. Hydrogen is a carbon free fuel that could play a pivotal role in our transition toward finding a more sustainable energy resource. Furthermore, excess power plant energy as well as curtailed power, due to the intermittent nature of most renewable energy sources, could be stored through hydrogen generation.

The Government of Canada is determined to position the country as a global leader in hydrogen technologies. Its Hydrogen Strategy for Canada, released in December 2020, aims to cement hydrogen as a key part of the country's path to net-zero carbon emissions by 2050. Seamus O'Regan, Minister of Natural Resources said: "As we rebuild our economy from the impacts of COVID-19 and fight the existential threat of climate change, the development of low-carbon hydrogen is a strategic priority for Canada." However, most methods currently used to produce hydrogen emit carbon dioxide themselves. Therefore, it is crucial to develop more sustainable hydrogen methods for substantial hydrogen generation at low costs.

Dr. Jianu and her team aim to advance clean methods of hydrogen production called thermochemical cycles, which undergo a series of chemical reactions at various temperatures to split water without releasing particulates or greenhouse gases into the atmosphere. Thermochemical cycles like the copper-chlorine (Cu-Cl) cycle have shown ample potential regarding zero carbon emission. The Cu-Cl cycle employs several reactions, as shown in *Figure 1*, to split water into its constituent compounds, hydrogen and oxygen, and in comparison with other thermochemical cycles, possesses lower temperature requirements. The common four-step Cu-Cl cycle consists of electrolysis, thermolysis, hydrolysis reactors, and intermediate steps to decompose water into its constituent elements (see *Figure 1*). One could improve the overall efficiency of the cycle by designing and implementing innovative heat recovery systems that convert heat to other forms of energy or reuse it within the cycle.

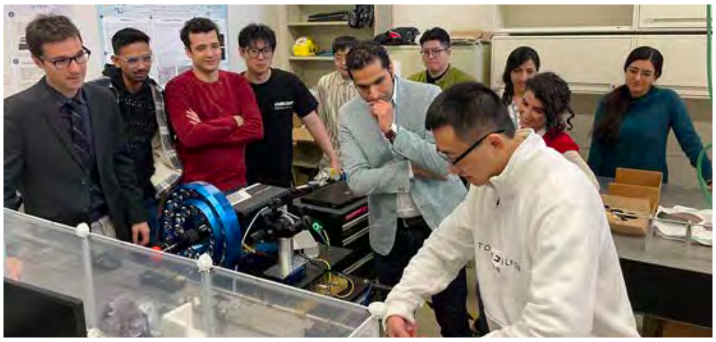
As such, Dr. Jianu and her team developed a novel heat exchanger consisting of a thermoelectric generator (TEG) within the Cu-Cl cycle, which enables electric power production that could be utilized in the electrolysis step of the cycle. This proposed TEG is numerically modeled using commercially available finite element software, COMSOL Multiphysics. The impact of the operational conditions on the performance of the TEG is investigated to provide insights for better understanding the system. Thus, a three-dimensional steady state model has been deployed and temperature and electric fields are solved simultaneously. It was found that a generated power of about 37.9 W and 34.7 W can be achieved for inlet temperatures of 530 °C and 480 °C, respectively[1].

This hydrogen research, performed in the Intelligent Fuels and Energy Laboratory (I-FuELs), is especially beneficial to Windsor, considering Ontario's and the U.S.'s efforts to adopt hydrogen as a clean fuel. As a border city, Windsor is well positioned to become the "green" hydrogen generation hub, connecting the Greater Toronto Area and the United States.

IMAGES COURTESY OF THE RESEARCHERS

University of Alberta
Dr. Mostafa Yakout

Additive Manufacturing of Next-Generation Materials



DR. YAKOUT IS DISCUSSING HIGH-SPEED COMPRESSION RESULTS WITH HIS TEAM ON RECENTLY FABRICATED AM PARTS *(PHOTO BY HECTOR GARCIA).*

Dr. MOSTAFA YAKOUT, PhD, P.Eng. (Alberta & Ontario) MASME, MCSME, MASTM

Yakout has been an Assistant Professor in the Department of Mechanical Engineering at the University of Alberta since August 2022. Prior to joining the University of Alberta, he was a postdoctoral researcher and instructor at McMaster University where he spent three years working on industrial applications of additive manufacturing. He also received his PhD from McMaster University in 2019, where he studied the process-structure-property relationships in laser powder bed fusion of aerospace alloys.

Dr. Yakout is currently the director of the Alberta Next-Generation Additive Manufacturing (ANGAM) laboratory at the University of Alberta. He established a research program, partially funded by the National Science and Engineering Research Council of Canada (NSERC), to develop and process next-generation metallic and ceramic materials containing rare-earth elements and critical minerals using additive manufacturing techniques. He is also an active voting member of the ASTM Committee F42 on Additive Manufacturing Technologies. Dr. Yakout holds a Professional Engineering (P.Eng.) license in Ontario and Alberta, and he is an Adjunct Research Professor at Western University.

Dr. Mostafa Yakout and his team are conducting research on additive manufacturing (AM) of metallic and ceramic materials containing rare-earth elements (REEs), such as niobium-rich titanium aluminides (Nb-rich TiAl), aluminum-scandium (Al-Sc) alloys, magnesium-neodymium-yttrium (Mg-Nd-Y) alloys, and rare-earth high entropy carbides. Dr. Yakout has established the Alberta Next-Generation Additive Manufacturing (ANGAM) research laboratory to study and provide the necessary scientific knowledge and methodologies for AM of next-generation material systems for applications in Canadian industries, such as energy (e.g., energy storage units, solid-state batteries, superconductors), defence (e.g., armor plates, naval ship structural components), aerospace (e.g., jet engines, rockets, airframe, waveguides), and automotive (e.g., electric vehicle batteries, high-performance heat exchangers). The research is centered on directed-energy deposition (DED), laser powder bed fusion (L-PBF), and binder jetting (BJ) AM processes. These AM processes have the capability to produce complex structures and components for several applications, such as future transportation systems, using a wide range of metallic and ceramic materials. However, some traditional materials, such as mild steel and alumina ceramic, tend to underperform when used in AM as a result of processing conditions that are not compatible with the material. Figure 1 shows an example of commonly observed defects in the L-PBF process, in which some of these defects are likely due to laser-material interactions. These defects can be reduced via developing AM-specific materials, such as materials containing REEs and critical minerals. For example, research has shown that adding REEs such as Y and Nb to gamma-TiAl leads to the formation of fine equiaxed grains during solidification and accordingly reduces the initiation of internal cracks. Dr. Yakout's research team leverages expertise in AM technologies, mechanics of materials, laser-material interactions, and powder processing to establish the link between process conditions, microstructures, and performance of end-user products (e.g., hydrogen storage units). His team uses state-of-the-art AM technologies to process materials containing REEs and critical minerals (e.g., Al-Sc and Nb-rich TiAl alloys) which offer unique properties, such as high resistance to hydrogen embrittlement, high corrosion resistance, improved magnetic properties, and superior mechanical strength at elevated temperatures. These alloys require specific melting, deposition, and processing methods during AM to avoid complex phase transformations and attain satisfactory mechanical properties (e.g., tensile strength, fatigue life, creep resistance). According to Canada's Budget 2023, critical minerals is one of the priorities in Canada's plan for a clean economy. Alberta, as a global leader in oil sands, has the essential tools, infrastructure, and knowledge to develop and manufacture next-generation materials containing critical minerals.

AM technologies enable the processing of multi-functional materials, such as shape memory alloys and high entropy alloys, that offer unique properties for several applications

...continued page 24

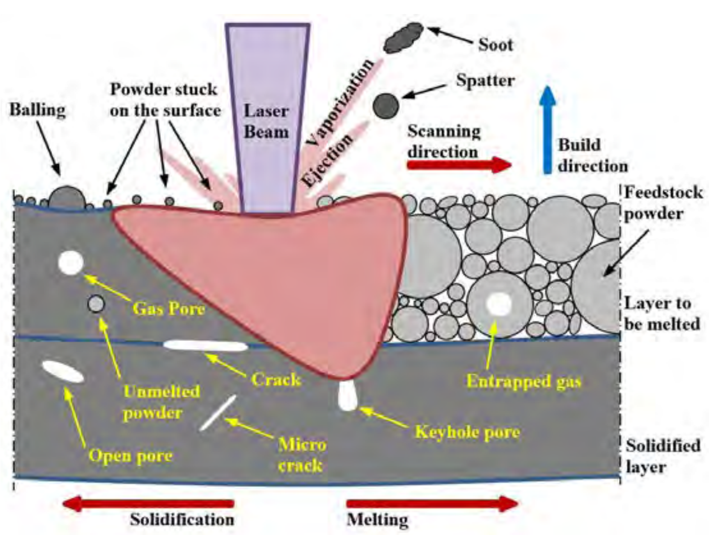


FIGURE 1: ILLUSTRATION OF PROMINENT DEFECTS IN THE LASER POWDER BED FUSION PROCESS [SOURCE: YAKOUT ET AL. (2018). A STUDY OF THERMAL EXPANSION COEFFICIENTS AND MICROSTRUCTURE DURING SELECTIVE LASER MELTING OF INVAR 36 AND STAINLESS STEEL 316L. *ADDITIVE MANUFACTURING* 24: 405-418].

Dr. Bodkhe, Multi-material Additive ***Manufacturing of Reconfigurable Structures (pg. 20):***

Current research projects in the team are aimed at increasing the load-bearing capacities of the multifunctional materials and creating control loops between the sensing and actuation portions. The lab is also working on upscaling the smart structures to be deployed into unmanned air vehicles and air mobility.

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*Dr. Yakout, Additive Manufacturing of Next-Gen-***eration Materials (pg. 23):**

(e.g., future transportation systems). It is becoming increasingly important to identify AM-specific materials that are tailored to offer enhanced performance without any metallurgical issues (e.g., vaporization of alloying elements) during the AM process. AM is not just about designing complex structures in industrial applications, the technology has been extended to developing complex material systems that can create a more efficient, sustainable, and accessible future for Canadians. Our research initiatives and collaborations with InnoTech Alberta (Canada), TU Dortmund University (Germany), Youngstown State University (USA), University of Texas at El Paso (USA), University of Waterloo (Canada), among several industrial partners help us to conduct inter-disciplinary high-quality research in AM of next-generation materials.

Together with Dr. André McDonald and his team in the Advanced Heat Transfer and Surface Technologies Laboratory, we develop ultra-high-strength high entropy alloy (HEA) coatings for heating and hydrogen embrittlement resistance applications. Dr. Yakout is also working closely with Dr. James Hogan and his team in the Centre for Design of Advanced Materials (CDAM) on AM of multi-functional, high-performance high entropy ceramics (HECs) for application in Canadian industries, such as energy, oil & gas, defence, aerospace, biomedical, and automotive. This collaborative work has been awarded the Research Exploration Fund from the Faculty of Engineering at the University of Alberta. The research program builds on Dr. Yakout's expertise and track record in fusion-based AM processes and Dr. Hogan's track record in mechanics of materials.

Passionate graduate students and researchers in the ANGAM laboratory enjoy working closely with national and international collaborators and industry partners to conduct research on linking process, structure, property, and performance in AM processes. Dr. Yakout and his team love the research that they do because they can see the real-life applications of parts and structures that they design and manufacture using new technologies and they are happy to devote their effort and time to serve the public. Dr. Yakout also enjoys developing and teaching manufacturing courses at the undergraduate and graduate levels. One of the most rewarding moments in his profession is when his students succeed, developing creative solutions for Canadian industry.

Dr. Akbarzadeh and Hossein Mofatteh, Shellular Metamaterials (pg. 16)

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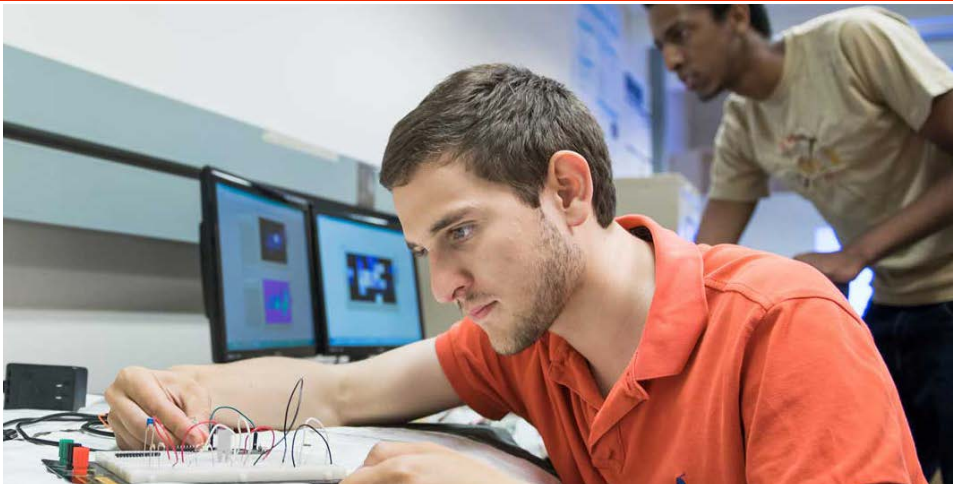
MECHATRONICS AND MANUFACTURING ENGINEERING EDUCATION AT THE UNIVERSITY OF BRITISH COLUMBIA (UBC)



I JOINED UBC AS A MANUFACTURING FACULTY member in 1986 and started to develop Manufacturing Automation Laboratory. As the founding Coordinator of Mechatronics and co-founder of Manufacturing Engineering Programs at UBC, I will briefly overview the history of both programs as follows.

The curriculum of the Computer Aided Automation (CAA) option was highly limited to training students in Mechatronics Engineering. Therefore, I proposed a five-year-long Electro-Mechanical Engineering (EMEC) with core courses from the Mechanical and Electrical-Computer Engineering departments in 1994 without any budget. Due to enrolment limits for their courses, we were allowed to accept only ten students per year by the EECE department. In addition to core Mechanical Engineering courses and Computer-aided Manufacturing (MECH491), the students took analog and digital circuits, computer architecture, software engineering, real-time operating systems, power electronics, and computer graphics subjects. The best students from the first-year common engineering class applied, and the candidates were selected based on their grades, affinity towards mechanical design and instrumentation, teamwork, and communication skills. The students took many credits in the last two years (49 credits/year) and spent eight months in an industry or research laboratory in teams of two students per project. The students were expected to design and build a fully operational computer-controlled machine or instrument in the industry. I supervised the projects jointly with the senior engineer of the company. The students graduated at the end of year five with bachelors and professional master of engineering degrees. The electro-Mechanical Engineering program became well known instantly after the impact of our first graduates in a few companies such as CREO (now Kodak), Teleflex (now Dometic), and TRIUMF.

EMEC became a highly successful mechatronics engineering education program. Prof. Farid Golnaraghi and his colleagues initiated a four-year Mechatronics Engineering Degree program at the University of Waterloo in early 2000, and we shared our curriculum with them. Waterloo received strong budget support from Ontario and started the first Bachelor of Mechatronics Engineering degree in Canada. He later moved to SFU and founded the Mechatronics Systems Engineering degree program. UBC also received a budget from BC Government to convert EMEC into a four-year Mechatronics Engineering Option in Mechanical Engineering in 2004. In addition to core electrical and computer engineering courses of EMEC, we created highly specialized courses in Mechatronics: MECH 366 (Modeling of Dynamic Systems), MECH 420 (Sensors and Actuators), MECH 421 (Mechatronics System Instrumentation), MECH 423 (Mechatronic Product Design) and MECH 467 (Computer Control of Mechatronics Systems). UBC hired faculty members with strong research programs in these core mechatronics areas. The last EMEC students built all of the laboratory equipment as their industrial design projects. The option continued to select the students as in EMEC, where grades, affinity to product design, hands-on skills, and teamwork skills are considered. The highly competitive option takes only 32 students per year, and almost a quarter of them continue to graduate schools to advance their expertise. Mechatronics graduates are primarily employed in BC's high-tech industries; some went to California's Silicon Valley. The graduates also created several high-tech start-ups in BC, which are growing rapidly (i.e., Zaber Technologies, Planar Motor, Excel-Sense Technologies, and Green Matters). UBC also developed a one-year professional master of engineering program in Mechatronics to upgrade mechanical engineers' knowledge.

Good engineering education is possible only if the core subjects are taught by faculty members with strong and active research in these areas, which are evolving rapidly in parallel to advances in computer, electronics, sensors, and actuator technologies. My core research area is machine tool and manufacturing automation engineering, which contains Computer Numerical Control of machines, material handling equipment, and inspection and measurement system, all mechatronics systems. UBC Materials and Mechanical Engineering Departments and School Engineering at the Okanagan campus jointly developed the "Manufacturing Engineering" degree program at UBC in 2018. The curriculum contains fundamental courses in solid mechanics, dynamics, fluid mechanics, thermodynamics, heat transfer, materials, and vibrations complemented by manufacturing processes (metal cutting, additive manufacturing, metal forming, welding), automation subjects (robotics, PLCs, computer control of mechatronics systems, measurement instrumentation) at Vancouver campus or production management at Okanagan campus. UBC hired fourteen faculty members in manufacturing at Vancouver and Okanagan campuses, where each accepts fifty students per year into the program.

Mechatronics and manufacturing engineering education and research are the engines of industrial economies that heavily rely on automation and cost-effective production of value-added goods. The industry needs well-educated engineers with professors who are innovative and active researchers having solid interactions with the industry. In addition, such engineers need to work with technical support personnel who are well-trained in handling modern factory equipment and tools.

Professor YUSUF ALTINTAS, MASc, PhD, Hon. Dr.Ing (Stuttgart), Dr.Cau. (Budapest), FRSC, FNAE, FACATECH, FSME, FASME, FCIRP, FEC, FCAE, FISNM, Fellow P&WC, and Fellow Tokyo Univ.

Professor Altintas is the NSERC – Pratt & Whitney Canada – Sandvik Coromant Industrial Chair Professor in Virtual Machining, founding director of Fraunhofer project in digital transformation in manufacturing, founding director of Mechatronics option and Distinguished Scholar at the University of British Columbia, and chief editor of CIRP Journal of Manufacturing Science and Technology.

PHOTOS COURTESY OF UBC

STUDENT AFFAIRS REPORT

CSME

WITHIN THE STUDENT AFFAIRS COMMITTEE we've been busy moving our two key initiatives forward through promoting more activity with CSME Student Chapters and engagement in the Student Design Competition. With respect to the Student Chapters, we have already had a number of institutions express interest and start work towards putting together a renewed local chapter. We have already had the University of Toronto and University of Alberta form a local CSME Student Chapter. Now that we have momentum going with more groups joining the CSME student network, we will begin moving toward increasing the networking among student groups. In addition to supporting local chapters as they plan professional development events, a primary goal of ours is to facilitate networking among students across the country with the hopes of more joint events where possible. We firmly believe this will lead to an improved student experience when participating in CSME Student Chapter events, in addition to helping students expand their professional networks. For any questions surrounding local CSME Student Chapters, please feel free to reach out to Dan Romanyk directly (dromanyk@ualberta.ca).

Following the lead of the National Design Competition Director, Grant McSorley, the details for this year's competition have been finalized. While we would have loved to host an in-person competition, the timeline would simply not allow it this year and the event will still be held remotely. The top projects will be selected in each of the following categories: i) sustainability, ii) commercial readiness, and iii) technical excellence in Mechanical Engineering. A cash prize of $750 will be awarded to the top design project in each category. Those that are interested in the competition may refer to the official site (http://csme-ndc.ca) or reach out to Grant McSorley (gmcsorley@upei.ca) directly. We plan to generate significant interest and involvement in this year's competition as we are aggressively targeting a return to an in-person National Design Competition for 2024.

CSME STUDENT CHAPTERS

EXPAND YOUR NETWORK

Do you have a Mechanical Engineering Group/Club at your Canadian university or college?

Are you interested in expanding your network and receiving support for professional development events?

The CSME Student Affairs Committee Chair, Dan Romanyk, is looking to help establish and connect with CSME Student Chapters across Canada to work with them on their activities and to help deepen their involvement in the Canadian Society for Mechanical Engineering/La Société Canadienne de génie mécanique (CSME-SCGM).

CONTACT DROMANYK@UALBERTA.CA

WWW.CSME-SCGM.CA/CONTENT/CSME-STUDENT-CHAPTERS

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The Canadian Society for Mechanical Engineering
A constituent society of the Engineering Institute of Canada

La Société Canadienne de génie mécanique
Une société constituante de l'Institut canadien des ingénieurs

NEWS COMMUNIQUÉ

Office of the President

March 2023

The Canadian Society for Mechanical Engineering (CSME), founded in 1970, is pleased to announce the winning recipients of its 2023 regular awards. These awards may be bestowed biannually to members of the society for their outstanding contributions to specific areas of mechanical engineering in Canada.

In addition to the three previously-announced technical award winners, six exceptional engineers will be presented with their awards on 30 May at the 2023 CSME International Congress to be held from 28-31 May at the Faculty of Engineering, University of Sherbrooke, QC.

Please consider attending the 2023 CSME International Congress to congratulate all of these exceptional award winners and network with your colleagues: www.csmecongress.org.

Robert W. Angus Medal

For "outstanding contributions to mechanical engineering practice in Canada, including industrial innovation, technology commercialization and creativity."

Muthukumaran Packirisamy, PhD, FCSME
Professor, Concordia University, QC

I.W. Smith Award

For "outstanding achievement in creative mechanical engineering within 10 years of PhD degree."

Hamid Akbarzadeh, PhD, MCSME
Associate Professor, McGill University, QC

New Fellows of the CSME

For "excellence in mechanical engineering and significant contributions to the progress of the profession."

Dana Grecov, PhD, 2023 FCSME
Professor, University of British Columbia

Ya-Jun Pan, PhD, 2023 FCSME
Professor, Dalhousie University

Hossein Rouhani, PhD, 2023 FCSME
Associate Professor, University of Alberta

Xiaohua Wu, PhD, 2023 FCSME
Professor, Royal Military College of Canada

Call for Nominations – 2024 CSME Awards

Nominations of CSME peers are currently solicited for three of the society's six technical awards, specifically CSME medals for outstanding contributions to the fields of Manufacturing, Fluid Mechanics and Solid Mechanics, and other annual 2024 awards. Note that members cannot nominate themselves – worthy candidates from the diverse CSME community must be nominated by CSME Fellows.

Deadline for Manufacturing, Fluid Mechanics and Solid Mechanics Technical Awards: 3**0 September 2023**

Deadline for other annual 2024 Awards: ***31 January 2024***

For Procedures, Terms/Criteria and the Nomination Form, visit: csme-scgm.ca/awards

PO Box 40140, Ottawa ON K1V 0W8
+1 (613) 400-1786 / admin.officer@csme-scgm.ca / www.csme-scgm.ca

Robert W. Angus Medal

Dr. Muthukumaran (Muthu) Packirisamy

Dr. Muthu Packirisamy, a Professor, Concordia Research Chair (CRC), University Research Fellow and Gina Cody Innovation Fellow at Concordia University, is the recipient of many awards, including Member Royal Society of Canada College, Fellows of National Academy of Inventors (NAI, U.S.), Indian National Academy of Engineering (INAE), Engineering Institute of Canada (EIC), Canadian Academy of Engineering (CAE), American Society of Mechanical Engineers (ASME), Institution of Engineers India (IEI), Canadian Society for Mechanical Engineering (CSME), CSME's I.W. Smith Award, Concordia University Research Fellow, Petro Canada Young Innovator Award, Gina Cody Research Excellence Award and ENCS Young Research Achievement Award. He has authored 510 research articles, one book, six book chapters, 49 invited talks, 32 inventions, obtained grants around $16 million and supervised more than 16 RA/PDF, 33 PhDs, 54 Masters and 71 undergraduates. His recent inventions on energy harvesting from photosynthesis of blue green algae and Direct Sound Printing have more than 400 citations worldwide.

I.W. Smith Award

Dr. Hamid Akbarzadeh

Dr. Abdolhamid (Hamid) Akbarzadeh Shafaroudi is a Canada Research Chair (CRC) in Multifunctional Metamaterials, an Associate Professor (Bio-inspired material design) in the Bioresource Engineering Department, an Associate Member (Solid mechanics) in the Mechanical Engineering Department, and the Director of Advanced Multifunctional and Multiphysics Metamaterials Lab (AM3L) at McGill University in Montreal. He joined McGill as a Faculty member in 2015 after two and half years of working on advanced architected cellular solids as an NSERC postdoctoral fellow in the Mechanical Engineering Departments at McGill University and University of New Brunswick. His research and training program at AM3L is aligned with systematic design, multiscale multiphysical modeling, and 3D printing of programmable and smart multifunctional metamaterials and metastructures. To date, his contributions have led to six patent applications/reports of invention and 118 published articles in high-impact journals like *Advanced Materials, Advanced Functional Materials*, *Advanced Science*, *Nature Communications*, *Acta Materialia*, *Carbon*, and *Applied Materials Today*.

Fellow

Dr. Dana Grecov

Dr. Dana Grecov is a Professor in the Mechanical Engineering Department at the University of British Columbia, specializing in Fluid Mechanics. Dr. Grecov is internationally known for her research contributions in fluid mechanics and rheology. She applies the concepts to conduct fundamental and applied research that has a high degree of novelty, on a range of subjects from liquid crystals and lubricants, to synovial fluids and CFD studies relevant to biomedical applications. Notable achievements include recent important translational applications to biodegradable lubricants for prosthetic joints and biological and industrial lubricants in general, with contributions to cellulose nanocrystalline materials, computational methods for complex fluids, important real-world application to modelling and simulations of industrial coking processes that are implemented by Syncrude Canada, and new fluid-structure interaction simulations of artificial aortic heart valves.

PHOTOS COURTESY OF THE RESEARCHERS

Fellow

Dr. Ya-Jun Pan

Dr. Ya-Jun Pan is an internationally renowned researcher, distinguished educator, and volunteer leader. She is a Professor at Dalhousie University and has made significant contributions in robust nonlinear control and cyber physical systems with in-depth applications to tele-robotics, cooperative and unmanned systems, intelligent robotics, rehabilitations, and industrial automation. Dr. Pan has contributed extensively to engineering and professional societies. She has been recognized with fellowships in Engineering Institute of Canada (EIC) and American Society of Mechanical Engineers (ASME), Research Excellence Award, and Alexander von Humboldt Research Fellowship. She has provided dedicated leadership and served as senior editor and associate editor for journals and conferences, IES AdCom member-at-large, technical and conference organizing committees, WiE chair and CSME keynotes, VP Atlantic of CSME, and NSERC evaluation group member. Dr. Pan has trained over 80 HQP who have joined industry or academia making significant contributions to the engineering society in Canada and worldwide.

Fellow

Dr. Hossein Rouhani

Dr. Hossein Rouhani is an Associate Professor in the Department of Mechanical Engineering at the University of Alberta and a Research Affiliate at the Glenrose Rehabilitation Hospital (Edmonton). He is also the founder and director of the Neuromuscular Control & Biomechanical Laboratory. He received a PhD degree in Biotechnology and Bioengineering from the Swiss Federal Institute of Technology in Lausanne (EPFL). Dr. Rouhani was then a postdoctoral fellow at the Institute of Biomedical Engineering at the University of Toronto. Dr. Rouhani's fields of research are in-field health monitoring using innovative wearable technologies and rehabilitative and assistive technology development. Within his translational research program, Dr. Rouhani has had several collaborative research projects with university hospitals to implement his developed wearable technologies in clinical research at these hospitals. Dr. Rouhani was the Congress Chair of 2022 CSME International Congress and is chair of the CSME Technical Committee for Biomechanics and Biomedical Engineering.

Fellow

Dr. Xiaohua Wu

Dr. Xiaohua Wu is a Professor in the Mechanical and Aerospace Engineering Department at Royal Military College of Canada. Dr. Wu was elected as a Fellow of the American Physical Society (APS) in 2015, and as an Associate Fellow of the AIAA in 2011. Aside from the CSME Fluid Mechanics Medal in 2021, he also received the Commandant's Medal in 2011, the John Scott Cowan Prize for Research Excellence in 2014, and the Principal's Medal in 2022 from the Royal Military College of Canada. He is being inducted as a CSME Fellow for his dedicated service to the CSME community and the broad Canadian Engineering community; for pioneering direct numerical simulations of jet engine turbomachinery flow, spatially developing transitional and turbulent boundary layer and spatially-developing pipe flow; for investigations on the origination of turbulent spots; for the discovery of turbulent-turbulent spots from fully-turbulent boundary layers; and for a high-impact inflow turbulence generation method that is being used by researchers and engineers worldwide.

CALL FOR SUBMISSIONS >>

Complex Fluids and Microfluidics

As the editors of the Canadian Society for Mechanical Engineering (CSME) *Bulletin*, we would like to invite you to submit any of the following items for consideration for publication in the next CSME *Bulletin* issue.

The next issue focuses on *Complex Fluids and Microfluidics* and will be published in November 2023. The guest editors of this issue will be the chair of the CMSE Microtechnology and Nanotechnology technical committee, Prof. **Mohsen Akbari**, and the co-chair of the CSME Microtechnology and Nanotechnology technical committee, Prof. **Martin Agelin-Chaab**.

- **Feature articles:** The aim of the featured articles is to give our readers an overview of a given sub-topic of the theme (Complex Fluids and Microfluidics), the most recent advancements in the area, and finally, the most critical aspects for future research. The article should be 1,200 words (9,000 characters including spaces) long. If you are interested in submitting a feature article, please submit an *Expression of Interest* (EoI) by sending a 300-word abstract of the article and a 50-word biography to either Marc Secanell (secanell@ualberta.ca) or Pouya Rezai (prezai@yorku.ca) by July 15th, 2023. The most significant contributions will be invited to submit a full featured article that will be due on October 1st, 2023.
- **Faculty spotlight:** This section highlights new faculty in the Mechanical Engineering Departments across Canada within four years of their appointment, ideally working on the topic of the issue (though not essential). The aim of this section is to introduce new faculty members to the CSME community; therefore, the article should provide a short biography, an introduction to your research (What is the topic of your research? Why is the research topic important?) and a description of your laboratory including past and future work. If you are eligible and interested in submitting an article, please submit an *Expression of Interest* (EoI) by sending a 100-word abstract and a 50-word biography to either Marc Secanell (secanell@ualberta.ca) or Pouya Rezai (prezai@yorku.ca) by July 15th, 2023. The most significant contributions will be invited to submit a full article (500 words or 4,000 characters) that will be due on October 1st, 2023.
- **Short news items** of interest to the ME community prior to September 15th, 2023.
- **Recognitions:** Highlighting the achievements of ME peers (not self) prior to September 15th, 2023.
- **In memorial:** Recognizing the passing of ME members prior to September 15th, 2023.

For examples of the above, please see previous issues at www.csme-scgm.ca/bulletin.

Thank you for your consideration. We look forward to hearing from you soon.

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