THE CANADIAN SOCIETY FOR MECHANICAL ENGINEERING
LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE
SPRING/PRINTEMPS 2019

BULLETIN

SPECIAL ISSUE ON

Energy

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CONTENT

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Editor's Letter

ACCESS TO ENERGY IS CRITICAL TO THE stability and prosperity of our society. The development of a sustainable, carbon-free energy system remains a global challenge that will require the ingenuity of our brightest engineers to be realized. Energy production and conversion technologies are in transition, the cost of solar and wind energy continues to fall, and electric vehicles now constitute over 2% of the market share of new car sales. Canadian mechanical engineers must be engaged on this energy transition, therefore we decided to focus this CSME *Bulletin* on energy and to highlight some of the energy technologies under development in Canada.

Canadian mechanical engineers are a part of the energy transition in many areas, from the development of solar, wind and fuel cell devices to improving conventional energy extraction and energy efficiency technologies. This issue highlights a few examples of Canadian mechanical engineers aiming to create the necessary technologies for developing a sustainable energy system. In particular, it highlights Dr. David Sinton's experiences using microfluidics to advance energy technologies, Dr. Mojtaba Kheiri's work on innovative wind harvesting technologies, and Dr. Sébastien Poncet's drive to improve energy efficiency in refrigeration systems.

The 2019 CSME International Congress will be held at Western University (UWO). For this issue's *ME Chair's Corner*, we asked Dr. Straatman, chair of the Department of Mechanical Engineering at UWO, to provide an overview of their university so that those visiting Western during the congress can enjoy his perspective. This article fits nicely with the *New Faculty Spotlight* section, introducing the remarkable new researchers at Ontario universities working in the area of energy and computer aided-design. The *Recognition* section highlights the achievements of our CSME colleagues over the past year. To conclude the issue, Dr. Marina Freire-Gormaly updates us on some of the student-led events organized by the CSME chapters in this issue's *Student Chapter Report*.

Our next issue will focus on artificial intelligence and robotics, and as always, it will continue to highlight new faculty at our universities. Please consider contributing to this next issue by providing either a feature or a faculty spotlight article. If you are interested in contributing, please stay tuned for our call for contributions in the next few weeks. Alternatively, you can also contact us directly. We will be delighted to receive your contributions and comments about the CSME *Bulletin* as well as your ideas to improve it in the future.

We hope you enjoy reading this issue,

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Transactions of the Canadian Society for Mechanical Engineering (TCSME)

I am happy to report on the accomplishments of the *Transactions* of the Canadian Society for Mechanical Engineering (TCSME) for the year 2018.

The year 2018 was the first year that TCSME was published by Canadian Science Publishing. During the year, 295 manuscripts were submitted and 59 were accepted for an acceptance ratio of 20%. We published four issues with a total number of 44 articles. As of May 2019, these 44 articles were cited 40 times based on Google Scholar and 17 times based on the *Web of Science* which is a good indication that the impact factor will grow in the future. The most cited article is currently:

"Nonsingular terminal sliding mode control of underwater remotely operated vehicles"
Yaoyao Wang, Fei Yan, Bo Tian, Linyi Gu, Bai Chen
Transactions of the Canadian Society for Mechanical Engineering, 2018, 42:105-115, doi.org/10.1139/tcsme-2017-0051

MARIUS PARASCHIVOIU, PhD, FCSME
Editor, TCSME
Professor, Mechanical, Industrial and Aerospace Engineering
Concordia University

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

President's Message

Dear CSME Colleagues,

TIME FLIES AND IT IS ALREADY TIME FOR **MY** NEXT LETTER AS PRESIDENT OF THE Canadian Society for Mechanical Engineering. The 2019 International CSME Congress is rapidly approaching. With nearly 400 papers to be presented during this congress and the associated meetings, I expect to meet many of you personally in London. A warm welcome to you all!

We have been working hard over the last six months addressing CSME issues. We have nearly 3,000 student members and this represents a lot of energy. We hope to channel this energy into constructive projects like assistance with science and technology fairs and other similar initiatives aimed at promoting STEM careers. We spent a lot of time setting up a proper organizational structure. We presently have CSME student advisors at nearly all engineering schools, and their first meeting/workshop will take place on the last day of the congress. I would like to ask all of you for suggestions on how to best utilize the energy of our student members so that I can bring your suggestions to this meeting.

CSME is a professional organization and its members represent a valuable know-how resource for our country. We are in the process of setting up websites for each technical committee, listing their members and expertise so that the relevant expertise can be found quickly. We hope that this database will soon become the main technical reference for Canadian expertise in mechanical engineering. We plan to have this database operational by the end of summer.

Best,

MACIEJ FLORYAN, Ph.D., P.Eng. FCSME, FAPS, FASME, FCAI, FEIC
CSME *President*
Professor, Western University
Department of Mechanical and Materials Engineering

Welcome New CSME members
as of 1 October 2018

Mr. Nnamdi Martin Alozie, Mechaserve Contracting and Servicing Company Nigeria Ltd.
Dr. Gabriele Barbaraci, York University
Mr. Ken Cooper, Kens Welding and Mechanical
Prof. Lucas Hof, École de technologie supérieure (ÉTS)
Prof. Xianke Lin, Ontario Tech University
Prof. Andre McDonald, University of Alberta
Prof. Ronald Miller, Carleton University
Dr. Bruce Minaker, University of Windsor
Mr. Patrick Morasiewicz, Stackpole International
Prof. Ryozo Nagamune, University of British Columbia
Mr. Fareed Noorani, MacDonald Layton Costain Ltd
Prof. Alison Olechowski, University of Toronto
Dr. Dipal Patel, Ontario Tech University
Dr. Keith Pilkey, Carleton University
Dr. Dan Romanyk, University of Alberta, School of Dentistry
Prof. Jaho Seo, Chungnam National University
Mr. Yogeendra Sreekanta, Subramanya Raj Cad Railway Industries Ltd.
Dr. Ali Tarokh, Lakehead University
Mr. Robert Vaisanen, University of Waterloo alumnus
Dr. Sima Yaghoubian, Hak Felez Mashhad Co.

Message du président

Chers collègues,

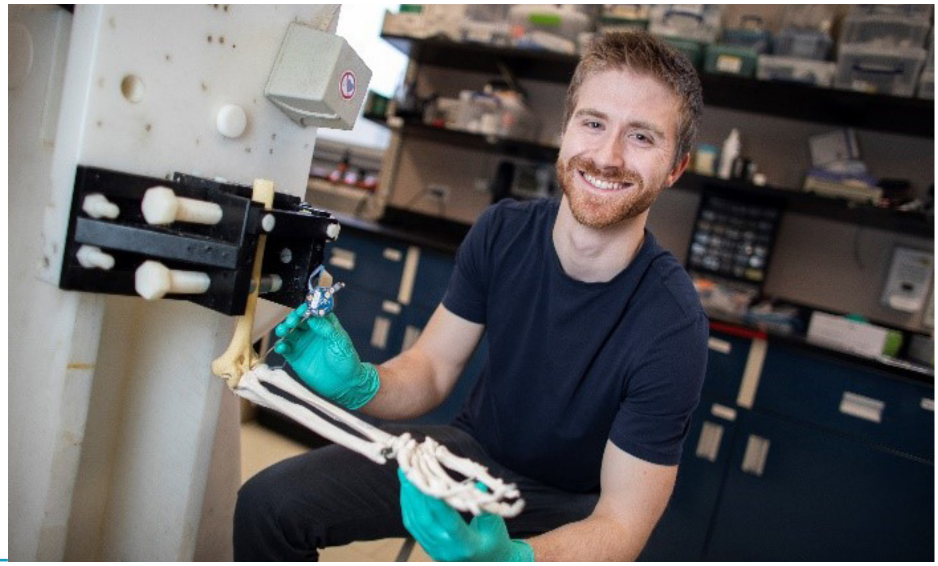
Le temps file et il est déjà l'heure de ma prochaine lettre en tant que président de la Société canadienne de génie mécanique. Le Congrès international SCGM 2019 approche à grands pas. Avec près de 400 communications devant être présentées lors de ce congrès et des réunions associées, je compte rencontrer personnellement nombre d'entre vous à Londres. Bienvenue à vous tous!

Nous avons travaillé dur au cours des six derniers mois pour résoudre les problèmes du SCGM. Nous avons près de 3000 membres étudiants et cela représente beaucoup d'énergie. Nous espérons canaliser cette énergie dans des projets constructifs, tels que l'assistance à des salons scientifiques et technologiques et d'autres initiatives similaires visant à promouvoir les carrières dans le domaine des "STEM". Nous avons passé beaucoup de temps à mettre en place une structure organisationnelle appropriée. Nous avons actuellement des conseillers étudiants SCGM dans presque toutes les écoles d'ingénieurs et leur première réunion / atelier aura lieu le dernier jour du congrès. J'aimerais vous demander à tous des suggestions sur la meilleure façon d'utiliser l'énergie de nos membres étudiants afin que je puisse les apporter à cette réunion.

SCGM est une organisation professionnelle et ses membres représentent une précieuse ressource de savoir-faire pour notre pays. Nous sommes en train de mettre en place des sites Internet pour chaque comité technique, répertoriant leurs membres et leurs compétences, afin de pouvoir trouver rapidement les compétences pertinentes. Nous espérons que cette base de données deviendra bientôt la principale référence technique de l'expertise canadienne en génie mécanique. Nous prévoyons que cette base de données sera opérationnelle d'ici la fin de l'été.

Meilleur,

Preparing Well-Rounded Engineers for Dynamic Careers in a Global Market



DAVID AXFORD, A GRADUATE STUDENT IN THE BIOENGINEERING RESEARCH LABORATORY AT THE HAND AND UPPER LIMB CENTRE, IS SHOWN CONDUCTING DIGITALIZATIONS OF BONE LANDMARKS TO CONSTRUCT COORDINATE SYSTEMS FOR THE ARM AS PART OF AN EXPERIMENTAL STUDY TO QUANTIFY THE EFFECT OF SURGICAL RECONSTRUCTIONS OF THE ELBOW.

Dr. A.G. STRAATMAN, PhD, P.Eng. FCSME

Dr. Anthony Straatman is a Professor and Chair of the Mechanical & Materials Engineering Department at Western University. He completed his BESc and MESc degrees, both in mechanical engineering, from Western University in 1991 and 1992, respectively, and his PhD in mechanical engineering from the University of Waterloo in 1995, where he specialized in Computational Fluid Dynamics (CFD) and Turbulence Modelling. After working in the software industry for Advanced Scientific Computing (now ANSYS), he took up a professorship at Western University in 1997 and moved through the ranks to full professor by 2010. In his time at Western, he has served as Associate Chair Undergraduate and Associate Chair Graduate in the MME Department, and now leads the department as chair since 2016. Dr. Straatman has received multiple departmental, faculty and university teaching awards including the Edward G. Pleva Award, Western's highest award for excellence in University Teaching. He has served on the board of directors of the CFD Society of Canada, and as president from 2012-2014. He is also a Fellow of the Canadian Society for Mechanical Engineering (CSME) since 2016. Dr. Straatman supervises a staff of graduate researchers and works mainly in the areas of heat and mass transfer in porous media and energy transport in compressible and incompressible flows.

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THE MECHANICAL & MATERIALS ENGINEERING (MME) department at Western University is a research-intensive department offering a strong undergraduate program with many opportunities and features, and graduate professional and research programs at the MEng, MESc and PhD levels. The department has recently grown to 30 faculty members distributed almost equally among the broad areas of solid mechanics and materials, design and manufacturing, thermofluids, and biomechanics; growth which was undertaken to intensify research efforts in the department and to ensure that instructional expertise is available in all essential areas of MME. The expansion has attracted some of the most gifted academics from prestigious and prolific engineering schools globally, and has us poised to further enhance our research output and continue to climb the world rankings. In 2018, Western MME was ranked 10th in Canada in both QS and THE rankings, and among the top 250 universities worldwide. The vision of the MME department at Western is to provide an environment where academics can excel in their research and students from around the world can enjoy intensive training at the undergraduate and graduate levels, leading to successful careers in engineering and research.

As a Faculty, Western Engineering has adopted the vision of graduating well-rounded engineers, competent in their chosen profession, with the skills to contribute to society in a professional, ethical and equitable way. The MME department places an emphasis on ensuring that our graduates have a strong fundamental understanding of the physics of the mechanical world on the premise that comprehension of complex engineering problems is predicated on the understanding of the fundamental physics of the component parts. Therefore, the primary objective of the program at all levels is to graduate mechanical engineers with an exceptional grasp of the fundamental science that underlies technology today. This understanding of "how things work" prepares our graduates to apply their knowledge in any subfield of mechanical engineering. A second related objective of the undergraduate curriculum is to maximize student exposure to hands-on activities in the form of laboratory and other practical exercises and opportunities. Whereas students in previous decades had many opportunities to develop practical mechanical skills, and hence were more likely to have an innate "feel" for mechanical systems prior to entering university, we find more and more that our incoming students often lack these skills.

Undergraduate Program — Western Engineering takes students into a general first-year, which includes coursework in applied mathematics, physics, chemistry, computer programming, statics, materials science and introductory engineering design, in addition to a compulsory non-technical course in business and management. Mechanical engineering takes between 90-120 students per year; up to 20% of the total first-year enrolment. The primary objective of "fundamental understanding" is reflected in the ME core curriculum by the breadth of core courses in Years 2 and 3. All technical courses in the third-year of the program are also compulsory, thereby preparing students to select any collection of technical electives in their final academic year. Throughout the core technical program, importance is placed on hands-on activities and projects, and this has become

WESTERN ENGINEERING STUDENTS AT THE KARLSRUHE INSTITUTE OF TECHNOLOGY (KIT) NORTH CAMPUS (MAY 2018), AT THE FACILITY THAT HOUSES A SCALED-DOWN FIELD COIL FOR SUPERCONDUCTORS.

a hallmark of the ME program at Western. To this end, considerable effort and investment has been made in the development of laboratory spaces and lab equipment. While in Year 2, lab activities are focused on fundamental concepts, many lab activities in Year 3 consider systems and processes. Across the compulsory part of the ME program, laboratory work is integrated into 75% of the courses.

Opportunity for further study and specialization in specific subject areas is then provided in the final year of study through the students' choice of five technical electives, enabling students to specialize in thermofluids, manufacturing, biomedical or materials engineering. Most of these technical elective courses also run physical labs to continue placing emphasis on the experiential element of the program. In addition, the ME design curriculum culminates in a capstone group project that runs for the full eight months of Year 4 and an opportunity to conduct an independent research project. In both of these culminating courses, prototype development and testing are encouraged, thereby further enhancing the experiential learning feature of the program. Western ME takes pride in the delivery of the technical program and has many top, award-winning instructors delivering courses. The program is strong, and while this alone is an attraction for students to select Western ME, it is some of the other features of our program that make it stand out among ME programs in Canada.

Engineering Plus: High achieving students have the opportunity to participate in the concurrent/combined degree programs with many other departments with the advantage that the student will receive two degrees in a reduced time-frame. The most popular combined-degree programs are in ME-business, ME-law and ME-computer science, but students have also combined ME-physics, ME-applied math, ME-economics and ME-music! The possibilities are virtually endless.

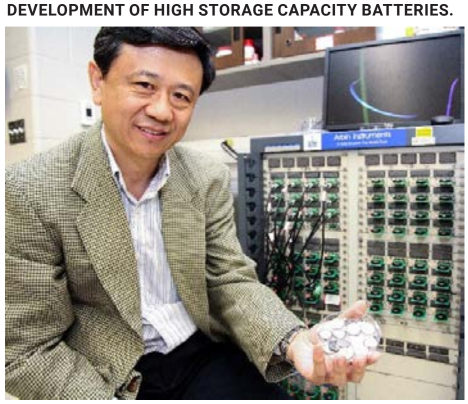
Summer Engineering Co-op/Internship Program: Western Engineering offers two programs designed to provide students with real-world experience prior to graduation. The Summer Engineering Co-op Program (SECOP) is designed to assist students in finding quality paid engineering work for the summer months. In the internship program, students spend 8-16 consecutive months working in a paid engineering position prior to the last year of their bachelor of engineering science (BESc). The internship provides a longer work term and more extensive experience than SECOP, which ensures that students are able to work on advanced projects, seeing them through to completion. This program is subscribed to by more than 50% of the ME class, which means that more than half of the ME class has a significant work experience prior to graduation.

International Opportunities: The MME department has introduced an advanced manufacturing course to give students in their final year an opportunity to travel abroad to earn a Year 4 technical elective. The first offering of the course in 2018 had 18 students travel to Karlsruhe Institute of Technology (KIT) in Germany for two weeks to take classes and conduct laboratory exercises instructed by KIT professors.

Practical Elements in Mechanical Engineering: Fanshawe College of Applied Arts and Technology, in collaboration with Western MME, has developed an eight-month certificate program (delivered in two 4-month modules) called "Practical Elements in Mechanical Engineering (PEME)". The PEME program is comprised of practical courses in machining, welding, metrology, etc., and gives university engineering students an opportunity to enrich their knowledge of practical side of their profession. Students in ME (and other programs) can take the PEME program one module at a time during the summer months, or academic terms by deferring their university studies.

The Graduate Program – MME offers a variety of professional MEng programs, and research programs at master's and doctoral levels. A key to the delivery of successful MEng programs is understanding that the program objective is different than that of the MESc program, and thus it is not appropriate to simply deliver the same courses for both purposes. MEng students develop some professional expertise on a topic, but not at the level of detail or understanding expected from someone training to be a researcher.

PROF. A. SUN'S RESEARCH FOCUSES ON THE DEVELOPMENT OF HIGH STORAGE CAPACITY BATTERIES.



In terms of numbers, in 2017 Western MME had 115 graduate students in its programs. In the same year, Western ME graduated 28 MEng students, 16 MESc students and 10 PhDs. In 2018, these numbers are 31, 19 and 8, respectively. These numbers put Western ME in the company of the most research-intensive schools in Canada, and among the very top engineering schools in Ontario, according to annual reports by Engineers Canada.

Research in Mechanical & Materials Engineering – The success of the graduate program in MME is tied very closely to the strength of the research enterprise in MME; an enterprise that enables us to attract the very best domestic and foreign graduate students. In research, the focus has always been on impact and this is shown consistently by metrics published by *Thomson Reuters for the Association of American Universities and Canadian Peer Institutions*. The report published for 2012-16 shows Western engineering at 3rd in Canada for publications per faculty member – behind only McGill and U Alberta – and 3rd in Canada for citations per publication – behind only U Toronto and U Waterloo. This is a testament to the research excellence that our researchers espouse.

Professor A. Sun, a Fellow of the Royal Society of Canada, leads one of North America's most prolific laboratories in energy materials & energy storage and a team of nearly 30 graduate students and postdoctoral fellows. He is one of the most highly-funded Canadian researchers in energy materials. His research focus is on the development of batteries with high storage capacity for electronics and transportation needs and his most recent work on lithium-sulphur batteries has the potential to revolutionize chemical energy storage by offering higher energy batteries at a substantially lower cost. His research appears regularly in the very top journals, including *Nature Communications*, and he was named a Highly Cited Researcher by *Web of Science* in 2018 for having multiple papers that rank in the top 1 per cent by citations for field and year.

The Fraunhofer Project Centre (FPC) for Composites Research is a joint venture between Western University and the Fraunhofer Institute of Chemical Technology (ICT) in Pfinztal, Germany. The FPC at Western develops, tests, validates and characterizes new lightweight materials and advanced manufacturing processes at industrial scale.

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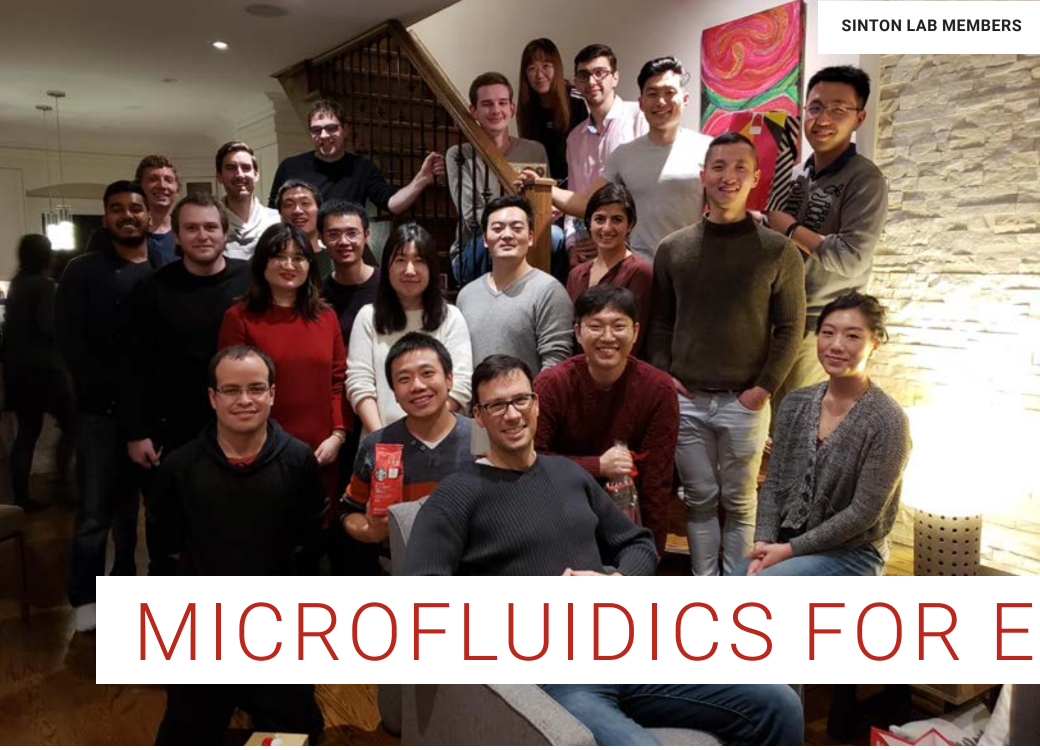


SINTON LAB MEMBERS

MICROFLUIDICS FOR ENERGY

From conventional to renewable energy and fuels

DR. DAVID SINTON, FCSME, FEIC, FASME, FAAAS

D. Sinton is a Professor in the Department of Mechanical & Industrial Engineering at the University of Toronto, and the Canada Research Chair in Microfluidics and Energy. Prior to joining the University of Toronto, he was an Associate Professor and Canada Research Chair at the University of Victoria and a Visiting Associate Professor at Cornell University.

IMAGES COURESTY OF THE RESEARCHER / UNIVERSITY OF TORONTO

I THANK THE EDITORS FOR THE OPPORTUNITY to write my perspective on the field of microfluidics for energy applications, and our path within that field. I start with the global energy system that motivates this work, and then provide examples of our contributions, and ambitions, in the areas of conventional and renewable energy systems.

In the long history of the global energy system, scarcity or fear of scarcity has been the norm. In stark contrast, our present is a time of surplus – both of conventional and renewable resources. First with respect to conventional resources, fossil fuel sources have enabled the development of the modern world, and continue to provide for ~ 85% of global energy production as shown in *Figure 1* with data from the *BP Statistical Review of World Energy* (2017). Due in large part to the combination of horizontal drilling and hydraulic fracturing, the U.S. has led a revolution in oil and gas recovery and have turned the world's largest consumer of oil and gas into a major global producer, once again. The implications of this change for Canada are much discussed in the media – the biggest customer for Canadian oil and gas having become a major producer – but the implications of oil and gas surplus go well beyond North American borders. Global coal reserves are also vast and robust despite consumption continuing at near-record levels worldwide. While these fossil sources are ultimately finite, technology continues to unlock vast fossil resources and this trend is likely to continue for some time.

As traditional concerns over energy shortages are fading, concerns over the environmental implications of fossil fuel consumption are growing. Chief among the causes for concern is the CO_2 emitted with the consumption of the fossil fuels that underwrite our current way of life. CO_2 emissions are at record levels (~ 37 Gt in 2018) as are measurements of CO_2 concentrations in the atmosphere. The most recent meeting of the Intergovernmental panel on Climate Change both made an urgent case for action, and highlighted the decades-long timescales required for change in the energy system [*Nature* 564, 22 (2018)].

Fortunately, another form of energy surplus is emerging, that of cheap renewably generated electricity. A decade ago it was not clear which of the many forms of renewable energy technology would become dominant. With advances in performance and parallel advances in manufacturing, the cost of installed solar power capacity has dropped precipitous over the last few years. All energy sources, and particularly all renewable energy sources, must now reconcile with the reality of cheap renewable electrons generated by solar. The implications of this coming surplus of renewably generated electricity will be vast. The consumption of fossil chemical energy to produce electrical energy is a foundation of thermofluids training in traditional mechanical engineering programs: The conversion efficiencies from thermal energy to heat are low, but the resulting electrical energy is of sufficiently high value to justify the cost. To those of us accustomed to thinking about the energy system in these conventional terms, the advent of plentiful renewable electrons is both exciting and disorienting. The importance of the familiar challenges associated with thermal-to-electrical energy conversion and energy scarcity wane, while the challenge of electrical energy storage comes to the fore. Electrical energy storage becomes the emerging challenge, both due to the inherent intermittency of the resource and seasonal variability of solar energy throughout most of the world. I'll return to this theme of storage at the end.

EARLY DAYS FOR MICROFLUIDICS & ENERGY

My professional interest in energy began in 2003 with my first faculty position at the University of Victoria. My doctoral studies focused on microfluidics – the study and application of

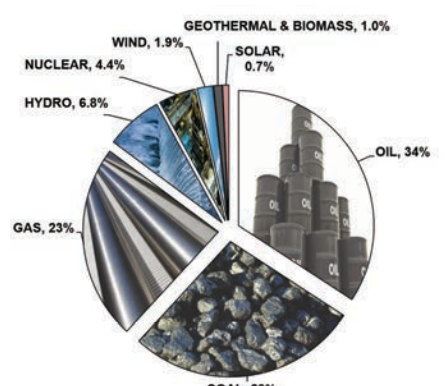


FIG. 1: TOTAL GLOBAL PRIMARY ENERGY CONSUMPTION BY SOURCE, ADAPTED FROM THE 2017 BP STATISTICAL REVIEW OF WORLD ENERGY.

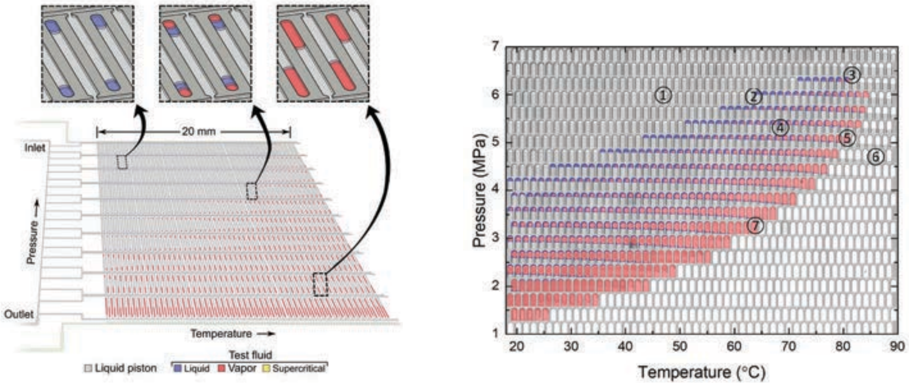


FIG. 2: PRESSURE-TEMPERATURE PHASE DIAGRAM CHIP (LEFT). IMAGES OF 1,000 INDIVIDUAL MICROFLUIDIC REACTORS INDICATING THE CHARACTERISTIC REGIONS OF THE PHASE DIAGRAM (1) LIQUID (2) BUBBLE POINT LINE (3) CRITICAL POINT (4) TWO PHASE ENVELOP (5) DEW POINT LINE (6) GAS REGION. REPRODUCED WITH PERMISSION FROM XU ET AL. "THE FULL PRESSURE–TEMPERATURE PHASE ENVELOPE OF A MIXTURE IN 1000 MICROFLUIDIC CHAMBERS" ANGEWANDTE CHEMIE, 2017, 56, 13962, COPYRIGHT WILEY-VCH VERLAG GMBH & CO. KGAA.

transport phenomena at the microscale – and the only application area that I had considered was biomedical. The case for microfluidics in biomedical applications is well supported and the Canadian ME community has contributed significantly to that field, as nicely discussed in the Fall 2018 *CSME Bulletin* issue on bioengineering. While I did pursue biomedical applications as a faculty member at UVic, I was increasingly drawn to energy projects within the Institute for Integrated Energy Systems (IESVic). The Institute was a boon to my research program and I benefited greatly from those collaborations, most notably with my UVic colleague and mentor Dr. Ned Djilali (FCSME). Ned encouraged me to think about how the collective suite of microfluidic methods could inform on transport phenomena in conventional microstructured fuel cell electrodes, and how microfluidics could enable new fuel cell architectures. My sabbatical at Cornell University was an opportunity to further explore new directions at the interface of microfluidics and energy systems. Thanks to the foresight of Carbon Management Canada, I returned to Canada with a major research project linking five research groups from across Canada. This research program focused on applying microfluidics to understand transport and reactivity of CO_2 in the subsurface with the goal of informing on carbon sequestration efforts.

Carbon sequestration is a form of CO_2 mitigation where emissions are captured, for instance from a flue gas, and buried deep in the subsurface, for instance into a saline aquifer. At the time of our project, our microfluidic experimental methods could not withstand the high pressures characteristic of deep subsurface CO_2 sequestration reservoirs. However, microfluidic methods did prove useful both in characterizing transport in the porous media and in measuring relevant fluid properties such as the diffusivity of CO_2 into a reservoir fluid.

Our work on subsurface CO_2 generated interest from a technology group at a Canadian energy company, who partnered with our group to develop microfluidic methods that could screen additives and conditions to improve the efficiency of Canadian oil operations. Perhaps because I was so accustomed to working with microscale systems, I was intrigued that our systems could inform on processes of the immense scale and energy intensity of Canada's steam-assisted gravity drainage process. This funding enabled us to increase the pressure capacity and robustness of our systems. Our micromodel systems proved useful in this sector – chiefly because they provided a means to visualize pore-scale processes directly within these complex multicomponent thermofluid systems. The operators were then better able to understand the impact of chemical additives in their operations and thus deploy such strategies with greater precision, greater efficiency and less waste. Microfluidic fluid property measurements also proved to be useful in supporting reservoir engineers and process modellers.

Through this early work it became clear that microfluidics in combination with microscopy could inform on conventional energy systems in two modes: First, a two-dimensional micromodel can serve as a planar replicate of the microstructured pore-space, providing a window into pore-scale processes and mechanisms. Second, microfluidic channels can be designed to coordinate and control fluid-fluid interactions and reveal mutual physical properties of interest such as diffusion coefficients, solubilities, minimum miscibility pressures and contact angles.

Phase behaviour is particularly important for industrial fluid processes. We were first supported in this area by a consortium pursuing safe pipeline transport of CO_2. Impurities are the norm in industrial fluids of all kinds, and in the case of CO_2, liquid phase water formation (dew point) is of particular interest. We developed microfluidic methods that were small scale versions of the classical measurement approaches. Although these microfluidic-mimic approaches worked sufficiently, they did not take full advantage of the control and multiplexing offered by microfluidics. Inspired by the classical P-T mixture phase envelop – familiar to mechanical and chemical engineers – the group sought to develop a chip that would provide all P and T combinations in parallel. The resulting system enabled 1000 parallel measurements of phase behaviour and was the first direct visualization of the classical fluid phase diagram, as shown in Figure 2 [Yi et al., *Angewandte Chemie*, 56, 13962 (2017)]. We later extended this approach to investigate phase behaviour at nanoscales, a fascinating regime wherein the degree of confinement influences the phase behaviour under test.

CANADIAN START-UP TECHNOLOGY TRANSFER

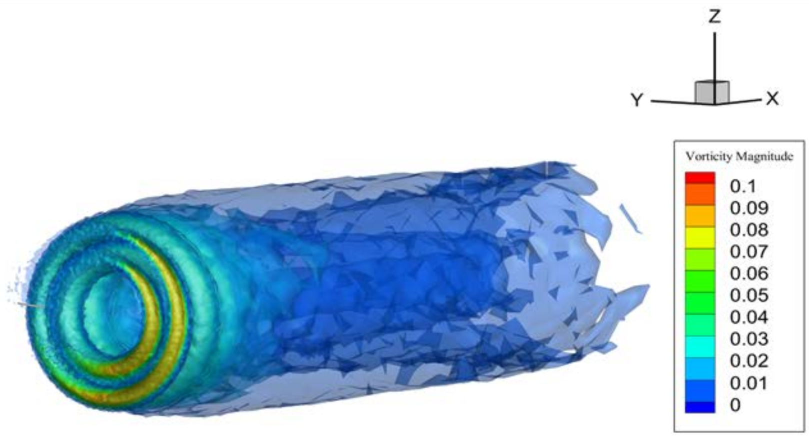
The potential for commercial development of microfluidics in energy applications was realized in our earliest work, but only acted upon through the vision and hard work of Tom de Haas, an MASc graduate from my group, and Stuart Kinnear, an MBA. Together we co-founded Interface Fluidics Ltd. and under the excellent management of Stuart (CEO) and Tom (COO) the company has grown to over 15 people with laboratory facilities in Edmonton and business office in Calgary. The company continues to develop the technology while providing a suite of microfluidic testing services for many of the largest oil, gas, and chemical companies worldwide.

CURRENT WORK

Right now in my lab we are pursuing directions that leverage the tools of microfluidics and nanofluidics for renewable energy and CO_2 conversion. We are working in partnership with the geothermal energy industry to develop bespoke fluids that can offer improved performance while being robust to the conditions in that demanding process. In the area of energy storage we see many technologies capable of providing for short term electrical energy storage needs, but a lack of technologies capable of addressing the seasonal storage challenge central to solar deployment outside of equatorial regions. We are partnered with electrocatalysis experts and developing fluidic systems technologies to transport reactants and products and maintain the local conditions required for efficient conversion of CO_2 into valued products such as ethylene. This approach provides both an avenue to store renewable electrical energy as well as offset the demand for fossil fuels by providing fuels and feedstocks directly from CO_2. It is a large scale challenge for small scale technology, and one that is motivating an excellent student team, CERT, that is a finalist in the $20M COSIA Carbon XPrize.

I'm excited about the future of this growing field and upbeat about the prospects for significant long term impact. I feel fortunate to have been able to contribute alongside many outstanding students and postdoctoral fellows. Those contributions would not have been possible without generous support of industrial sponsors, the Natural Sciences amd Engineering Research Council of Canada (NSERC), Alberta Innovates, the Canada Foundation for Innovation and the Ontario Research Fund.

Airborne Wind Energy: A Game Changer in ***Wind Energy***



ISO-SURFACE PLOT OF VORTICITY SHOWING THE FORMATION OF THE WAKE STRUCTURE DOWNSTREAM OF A LARGE-SCALE (~ 5 MW) CROSSWIND KITE. THE GREY RECTANGULAR REGION IN THE FIGURE REPRESENTS THE KITE.

Dr. MOJTABA KHEIRI, PhD, P.Eng., MCSME

Dr. Kheiri is an Assistant Professor in the Department of Mechanical, Industrial & Aerospace Engineering at Concordia University. He received a BSc (2005) and a MSc (2008) in aerospace engineering, both from Sharif University of Technology and a PhD (2014) in mechanical engineering from McGill University. Prior to joining Concordia University in 2017, he worked as a senior researcher for nearly two years on several wind power generation and energy storage projects. He is the director of the Fluid-Structure Interactions & Aeroelasticity Laboratory at Concordia University. His current research focuses on the aerodynamic modelling of crosswind kite systems, vortex-induced vibrations of offshore platforms, and aeroelasticity and control of aircraft wings.

IMAGES COURESTY OF THE RESEARCHER

WIND ENGINEERING CONCERNS THE STUDY OF the effects of winds in the atmospheric boundary layer on man-made and natural structures. It is at the intersection of several engineering disciplines, such as mechanical, civil and electrical engineering, as well as meteorology. In addition to devising ways to mitigate or suppress the undesirable effects of winds, wind engineering seeks developing methods and technologies for harnessing wind energy. Wind energy is environmentally-friendly, sustainable and abundant and it can be considered as a reliable source for fulfilling part of the world's energy needs. It is estimated that the wind energy will capture 5% of the world energy market by 2020[1]. According to the Canadian Wind Energy Association, Canada is home to the world's ninth largest wind generating fleet which currently can meet about 6% of our country's electricity demand (~ 3.3 million homes)[2].

Today, the Danish concept wind turbines, i.e. three-blade horizontal-axis wind turbines (HAWTs) facing wind flow, seem to capture almost fully the utility-scale energy market. This is the result of decades of research and development (R&D) which has led this concept to reach a nearly mature level. Wind turbines are, however, constantly growing in size in order to generate more power – becoming larger means capturing more and higher, stronger winds. Currently, the world's largest wind turbine is 187 meters tall (hub height), has three 80-metre blades, and has the power capacity of 9.5 MW. Wind turbines of 12 MW capacity will be launched in a few years from now.

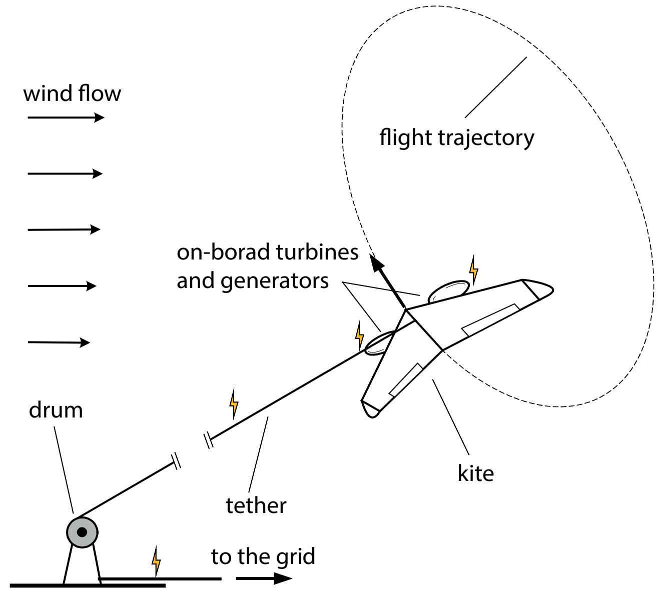
Innovative R&D, for example, on the blade design, materials used to fabricate blades, and on blade manufacturing methods has to be carried out to allow for the wind turbines growth trend to continue. Segmented (or modular) blade design concept, which allows for easier manufacturing and transportation, is an active research topic. Concepts, such as the bio-inspired downwind pre-aligned rotor, have also been put forward to reduce blades mass. Further research is also warranted on fatigue behaviour of composites and the effects of imperfections, residual stresses, and crack initiation.[3] Moreover, developing passive and active methods for noise attenuation, particularly the aerodynamic noise, such as wall-normal boundary layer suction, is a subject of constant research [4].

A major development in wind energy took place during the last decade, and that is the rapid growth of offshore wind energy. The global offshore wind energy installed capacity was only 2 GW at the end of 2009, while currently, Europe alone, has a total installed offshore capacity of over 18 GW. A combination of several factors, such as limited inland space for installing a multitude of wind turbines, minimal visual and noise impacts, and governmental incentives, in addition to stronger and steadier offshore wind resources, has led to the rapid deployment of offshore wind energy. This becomes more sensible when we learn that hundreds of millions of people worldwide live within a close proximity of a shoreline. For example, in 2001, over 11 million Canadians (nearly one-third of the country's population) resided within 20 km of a coast[5].

Unlike the onshore wind energy technologies and designs for the utility scale, which have reached an almost fully-developed state, there are several technological challenges to the offshore wind energy: harsh, corrosive marine environment, wave and sea currents interactions, and floating foundations development for deep water installations, are just a few. In addition to technical challenges, environmental risks to marine habitats also impose some challenges to the development of offshore wind farms. Motivated by the marked differences between onshore and offshore installations, some researchers have been pursuing different concepts of wind turbines, such as Darrieus type vertical-axis wind turbines (VAWTs), as promising alternatives to conventional HAWTs for offshore wind power generation. Extensive research is also being made on the dynamics, load analysis, control, life-cycle assessment and cost estimation of various concepts of offshore platforms, especially floating platforms.

Another growing trend in wind energy is to exploit wind resources in urban areas, either by retrofitting wind turbines onto existing buildings, or by fully integrating wind energy systems into the architecture, such as the Bahrain World Trade Center[6]. Wind flows in urban areas are characterized by low speeds, high turbulence and frequent change in direction. These conditions impede the wind resource assessment, considerably reduce the power output and capacity factor and shorten the fatigue life of the turbines. Current research in this area aims to improve the performance of micro-wind turbines used in urban wind energy applications as well as to tackle issues, such as noise, safety and visual impact. State-of-the-art research suggests that enclosing the roof-mounted turbines within guide vanes, in a diffuser or a shroud will significantly enhance the power output (by accelerating the incoming flow towards the turbine and increasing the effective capture area) and will minimize safety issues as well as noise and visual disturbances. Design concepts such as, omni-directional guide vanes and diffuser-augmented wind turbines are two popular examples[7]. On the other hand, onsite wind resource assessment in the built environment is difficult and costly, and thus not a common practice for micro-wind turbines. The lack of site-specific wind flow measurement hinders reliable performance prediction of wind turbines installed in the built environment. Current research attempts to compensate for inadequacies of in-situ wind measurement by developing low-cost computational fluid dynamics (CFD) models for simulating wind flows around buildings[8].

Airborne wind energy (AWE) which concerns harnessing high-altitude wind energy using tethered flying kites or aerostatic airborne devices may be the most recent technological innovation in the wind energy area. AWE technologies are expected to make a paradigm shift in the global wind energy market by offering a quite low levelized cost of energy (LCOE) compared to the conventional commercial technology. They offer larger power output (as they reach stronger and more consistent winds) using much lighter supporting structures (as they are tethered instead of being mounted on heavy towers and foundations). Various concepts of AWE have attracted investment from some major Technology and Engineering players, such as Google, Airbus, Shell and ABB. Among many different AWE concepts, crosswind kite power systems (CKPS) are of particular interest to researchers and developers. Crosswind soft kites or rigid wings flying at high speeds transverse to the incoming flow have much larger power output compared to aerostatic AWE devices. CKPS typically produce electricity via either on-board turbines or by unrolling the tether from a drum. The former is commonly called on-board power generation, while the latter is referred to as ground-based power generation.



SCHEMATIC DRAWING OF A CROSSWIND KITE POWER SYSTEM IN THE ON-BOARD POWER GENERATION MODE. THE KITE FLIES AT HIGH SPEED TRANSVERSE TO WIND FLOW, AND ON-BOARD TURBINES SPIN ELECTRICAL GENERATORS AT HIGH RPM. POWER GENERATED ON-BOARD IS TRANSFERRED TO THE GROUND LEVEL VIA CONDUCTIVE MATERIAL EMBEDDED IN THE TETHER. THE PRESENT DRAWING IS INSPIRED BY THE GRAPHIC DESIGN MADE BY DAIDALOS GLOBAL GMBH (DAIDALOS-CAPITAL.COM).[11]

Experts have ranked "reliability" as the top challenge to the deployment of AWE technologies[9]. These technologies have to be able to autonomously operate in harsh weather conditions (rain, snow, lightning, etc.) and turbulent wind flows for months or years with minimal need for repair, maintenance and supervision. Thus, a great deal of research is presently carried out on the control systems, flight trajectory optimization and autonomous take-off and landing to improve reliability.

At the Fluid-Structure Interactions & Aeroelasticity Laboratory of Concordia University, we aim at developing more reliable tools for the aerodynamic and aeroelastic modelling of CKPS. We partner with New Leaf Ltd., a startup based in Vancouver, which holds several IPs on the efficient and power smoothing drive-train concept for ground-based power generation. Our investigations show that the existing theories and methods used for the aerodynamic performance prediction of a single or multiple crosswind kites are seriously deficient as they fail to consider the flow retardation or induction effects by the kites and the kite-to-kite aerodynamic interactions. We developed an analytical model to approximate the induction effects and to account for these effects in power output calculations. We showed that the existing modelling shortcomings can lead to quite significant overestimation of the aerodynamic performance and power output – for a large-scale CKPS with a simplified configuration, the power output overestimation was found to be around 20%[10].

In addition to developing low-fidelity but inexpensive models, we also carry out high-fidelity CFD simulations for crosswind kites using computational resources on Compute Canada. The CFD simulations confirm that a low-speed turbulent wake flow is in fact generated downstream of a CKPS, which extends to large distances before eventually vanishing altogether. The implication of this discovery is that when designing kite farms and optimizing their layouts, the aerodynamic interactions between neighbouring kites have to be considered, and the geometrical interference requirement, which seemingly is the sole basis for the current kite farms design, is necessary but certainly not sufficient.

In a recent study[11], we highlighted the major difference between the design philosophy of conventional wind turbines and that of crosswind kite systems. The design of the former is mostly driven by the swept area, while for the latter the design should be based on the kite planform area. It was then suggested that the kite-area-normalized power output is the appropriate metric for performance analysis of CKPS.

We plan to continue improving the wake flow studies by adopting large-eddy simulation flow solvers and reducing the cost of CFD solutions by only partially resolving the geometry of the

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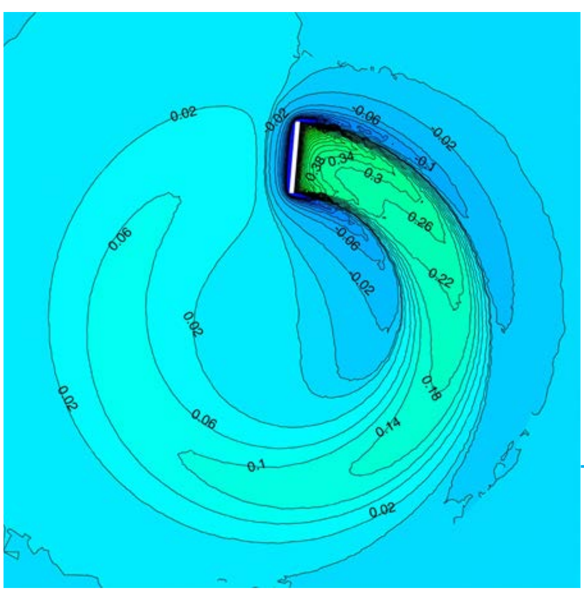

THE INDUCTION FACTOR CONTOUR PLOT FOR A LARGE-SCALE (~ 5 MW) CROSSWIND KITE SWEEPING AN ANNULUS IN THE AIR, PERPENDICULAR TO THE WIND DIRECTION – THE STRAIGHT DOWNWIND CONFIGURATION. THIS PLOT HAS BEEN OBTAINED FROM A CFD SIMULATION AND SHOWS THE RELATIVE MAGNITUDE OF RETARDATION OF THE ONCOMING FLOW IN THE VICINITY OF THE KITE. THE WHITE RECTANGULAR REGION IN THE FIGURE REPRESENTS THE KITE.

FIG. 1: MAP OF THE INSTANTANEOUS DENSITY GRADIENT FOR AN AIR SUPERSONIC EJECTOR WITH A RECTANGULAR CROSS-SECTION. RESULT OBTAINED BY LARGE EDDY SIMULATION USING THE AVBP SOLVER (PhD THESIS OF SERGIO CROQUER). THE OPERATING CONDITIONS ARE 5 BARS AND 300 K FOR THE PRIMARY FLOW, 0.974 BAR AND 300 K FOR THE SECONDARY STREAM AND 1.2 BAR FOR THE OUTLET.

Improving the Energy Efficiency of Non-Conventional Refrigeration Technologies

Dr. SÉBASTIEN PONCET, PhD

Sébastien Poncet (ing. Jr, PhD, HDR) is currently professor in the mechanical engineering department of Université de Sherbrooke (UdeS) and holds the NSERC chair on industrial energy efficiency supported by Hydro-Québec, Natural Resources Canada and Rio Tinto Alcan since 2014. He is directing the Laboratoire de Mécanique des Fluides, Thermique et Énergétique de l'Université de Sherbrooke LMFTEUS (mfteus.wordpress.com) focusing mainly on advanced numerical modeling of fluid flow and heat transfer in various complex systems ranging from thermal systems, turbomachineries or human airways, among other examples. Part of his research includes the experimental characterization of the thermophysical properties of complex materials, such as bronchial mucus, slurries, nanofluids and phase-change materials. During the last four years, the members of LMFTEUS were awarded 24 prizes or distinctions for the excellence of their research. Prof. Poncet is author or co-author of more than 200 publications whose almost 80 papers in peer-reviewed international journals.

IMAGES COURTESY OF THE RESEARCHER

THE WORLDWIDE ENERGY CONSUMPTION increased by 105% between 1973 and 2016, more rapidly than population according to the International Energy Agency (IEA). At the same time, the associated CO_2 emissions increased by 109%. The combined problems of depleting fossil energy resources and global warming became major concerns for the international community. An important fact is however less known. According to the Netherlands Environmental Assessment Agency, while the worldwide energy demand will continue to rise due to economic, demographic or societal factors and the availability of energetic resources will get scarcer, the energy demand for cooling will overtake the energy used for heating by 2060. It can be explained both by global warming issues and by the emergence of new refrigeration needs like the cooling of data centres and gas liquefaction.

At the same time, international initiatives are trying to regulate both harmful gas emissions and to phase out progressively the use of hydrofluorocarbon (HFC) refrigerants. Though having no ozone depletion potential (ODP), HFCs exhibit indeed high global warming potential (GWP) and long lifetimes. In 2018, the government of Canada launched a plan to limit HFC consumption by 85% by 2036, in line with the Kigali Amendment to the Montreal Protocol. It includes, among other things, the phase-out of high-GWP HFCs for condensing units or centralized refrigeration systems by January 1, 2020.

The refrigeration industry plays an increasing role in global economy. It gathers 3 billions of refrigeration, air-conditioning and heat pump systems worldwide, employs about 12 million people and consumes 17% of the overall electricity according to the International Institute of Refrigeration. Refrigeration does not only mean household refrigerators but concerns mostly the entire cold chain for food preservation and air-conditioning systems for the thermal comfort in residential, commercial and industrial buildings. These two domains are the cornerstones for the economic development of countries in hot and humid climates. Refrigeration finds also applications in ice rinks, chemistry, medicine… Mainly based on systems using harmful refrigerants, this industry has to face very important challenges during the next few years:

1. Energy savings: improvement of the energy efficiency of existing systems and / or development of new efficient technologies and / or scenarios;
2. Reduced dependence on fossil fuels by the use of waste heat or renewable energy sources;
3. Rapid introduction of alternative non-ozone depleting and low global warming refrigerants.

Points 1 and 3 have been clearly identified as the two priorities by the *International Journal of Refrigeration*, considered as the reference one in the field. To achieve To achieve these very challenging objectives, non-conventional technologies making real breakthroughs for cooling and refrigeration need therefore to be developed. Research activities performed by the Natural Sciences and Engineering Research Council of Canada (NSERC) chair on industrial energy efficiency established at Université de Sherbrooke in 2014 and supported by Hydro-Québec, Natural Resources Canada and Rio Tinto Alcan, go in this direction. The objectives are to improve the energy efficiency of some key components of refrigeration systems, namely ejector-based cycles, magneto-caloric refrigeration, transport of cold by ice slurries, CO_2 heat pumps integrating a transcritical ejector, simultaneous production of heat and cold by a vortex tube… and to progressively introduce more environmentally friendly refrigerants. Combined experimental, theoretical and numerical approaches are systematically preferred to better understand the heat and mass transfer in these systems and identify the main sources of exergy losses. It enables to finally propose new and more efficient designs and thermodynamic scenarios.

One fascinating thing is that most non-conventional refrigeration systems (in opposition with classical vapour-compression refrigeration systems) include very simple devices with no moving part, which have been invented a long time ago. The first example is the supersonic ejector (Figure 1). Introduced by Henri Giffard in 1859, it is composed of two convergent-divergent nozzles and serves to suck and compress a secondary fluid. Due to its relatively low efficiency, it fell more or less into oblivion. A renew of interest was born at the end of the 90s because of its numerous advantages (simplicity, ability to work with gases and liquids) and its capacity to lower the load of a compressor in a refrigeration system (single-phase ejector) or lower the losses due to the throttling valve (two-phase ejector). More than refrigeration, it can be used for desalination, CO_2 capture, the cooling of alternators… The second example is the vortex tube proposed by George Ranque in 1931. This simple device is able to produce simultaneously a hot and a cold stream from a single stream of compressed gas at the inlet as shown in Figure 2. Even though it has low efficiency, it does not include moving parts and does not require maintenance.

The second interesting point is that most of these non-conventional technologies can be used with low environmental impact refrigerants. Ejectors can be operated with CO_2 as working fluid to recover part of the losses usually encountered in the throttling valve and associated with a heat pump to increase its performance. When used to lower the load of a compressor, we showed that the drop-in replacement of R134a by hydrofluoroolefins (HFOs) with low GWP can be done in ejector-based refrigeration systems with almost the same overall performances. In magnetocaloric refrigeration, regenerators employ generally gadolinium plates or spheres (a rare earth) as refrigerant and cold is produced by a succession of Brayton cycles. Such refrigeration systems are now mature for household refrigerators at low magnetic fields or for cryogenic applications at high magnetic fields. The main obstacle to their large-scale commercialization still remains the prohibitive prize to extract rare earths. The last example is the use of ice slurry as refrigerant in secondary loops. Ice slurries are composed of liquid water, ice particles and eventually a low fraction of an additive like sodium chloride, ethanol… Ice slurries can transport cold very long distances for the air-conditioning of industrial buildings or the cooling of deep mining. They can serve also as a medium to store thermal energy in solar-driven cooling systems. From an environmental point of view, all these examples appear then as suitable alternatives to vapour-compression systems.

In all these refrigeration systems, the underlying physical mechanisms are usually quite complex to understand and very challenging to model by Computational Fluid Dynamics (CFD) as it may involve turbulent flow, train of oblique shock or condensation waves, conjugated heat transfer, phase change, multiphase or multicomponent flow, the coupling with a magnetic fields, complex geometries… It explains partly why researchers or engineers working in refrigeration use mainly hands on softwares, which provide stable and converged solutions in almost all cases. The main strength of LMFTEUS is to develop its own numerical 1D and 3D models, based on opensource libraries or research codes. Figures 1 to 3 display three examples of simulations realized by PhD students involved in the NSERC chair. My 12 years of experience at Aix-Marseille University working on the instability, turbulence and heat transfer in rotating flows enable me to import advanced numerical methods (high-order schemes, parallel computing, treatment of special boundary conditions…), which are completely new in the refrigeration sector and provide more accurate information about the fluid flow, heat and exergy transfers. We demonstrated that CFD may be considered as a very powerful and valuable tool to test some innovative concepts or simply change the heat transfer fluid or the design without requiring the same resources in time and cost as in experiments. As an example, Figure 3 displays velocity and magnetic fields obtained for three geometries of a gadolinium-based magnetic regenerator using a 3D opensource multiphysics solver. It enabled to demonstrate that increasing the tortuosity of the fluid flow may increase the cooling power of the regenerator without resorting to the build-up of multiple complex prototypes.

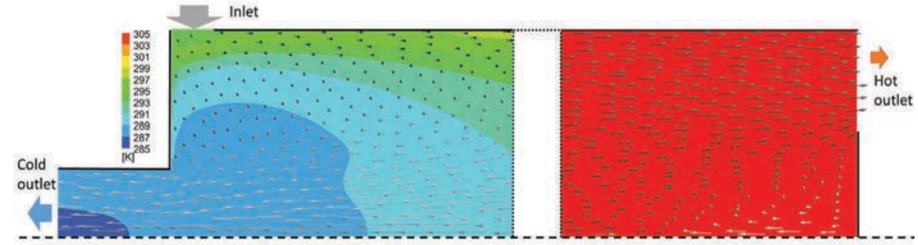

FIG. 2: TOTAL TEMPERATURE DISTRIBUTION AND VELOCITY VECTORS IN A RANQUE-HILSCH VORTEX TUBE WORKING WITH AIR. NUMERICAL RESULTS OBTAINED BY A K-Ω SST MODEL FOR A TOTAL INLET PRESSURE OF 2.39 BARS AND A COLD MASS FRACTION EQUAL TO 0.6 (PHD THESIS OF JUNIOR LAGRANDEUR).

The main strength of the NSERC chair on industrial energy efficiency is the complementarity between the different partners. Research at the university focuses on the in-depth understanding of fundamental mechanisms then on the development of new methods and tools. It allows scientific research not to dry up. The role of private companies and public agencies are first to demonstrate the potential benefit of new technologies at the pilot scale and second to ensure the technological transfer to the user sector. Generally speaking, working in such an ecosystem with universities, research centers and companies is crucial for the success of any refrigeration project and achieves the objectives fixed by the governmental policies.

My vision for the close future of refrigeration would be first the better understanding of fundamental mechanisms like the mixing of two streams in supersonic ejectors or the temperature separation in vortex tubes, which remain the subjects of intense debates in the community. With the constant increase in computational resources, CFD tools associated with appropriate analysis methods, like the exergy tube concept proposed by Lamberts et al. (2017)[1], should

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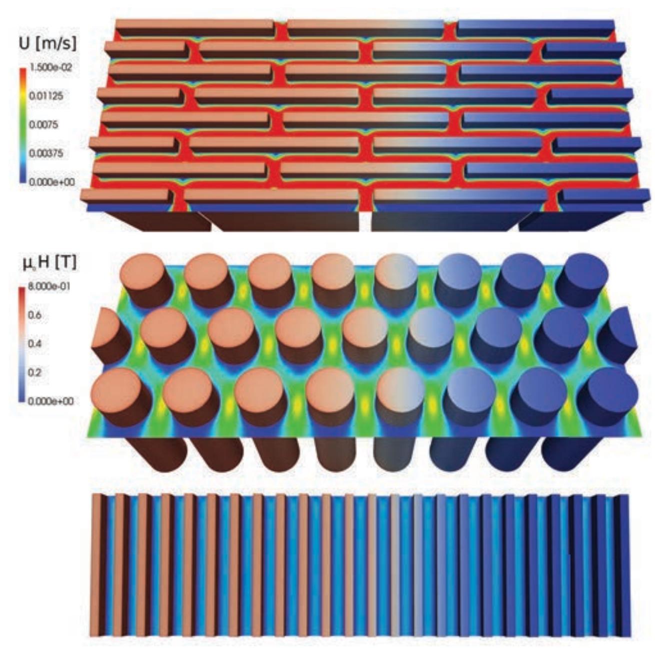

FIG. 3: MAGNETIC AND VELOCITY FIELDS OBTAINED AT THE MIDDLE OF THE HOT SURGE FOR THREE ACTIVE MAGNETOCALORIC REGENERATORS, COMPOSED, RESPECTIVELY, OF STAGGERED PLATES, STAGGERED CIRCLES AND STRAIGHT PLATES. RESULTS OBTAINED BY A 3D MULTIPHYSICS SOLVER DEVELOPED UNDER THE OPENFOAM LIBRARY FOR AN UTILIZATION FACTOR AND A POROSITY FIXED TO 0.6 AND 0.625, RESPECTIVELY (PHD THESIS OF IBAI MUGICA).

From the Lab to a Spin-off

INTERFACES, WHERE TWO OR MORE BULK phases meet are receiving an ever-greater attention by industry and academia. This is due to importance of interfaces in developing new mechanical systems especially for miniaturized systems such as lab-on-a-chip, implementation of new materials, advanced manufacturing methods, such as additive printing techniques, and two-phase flow systems, with or without heat transfer (e.g. boiling or sprays).

Two of the fundamental properties for interfaces are: surface tension (or surface energy) and wetting as characterized by contact angles (see Fig. 1a). Contact angle and liquid interfacial tension also play important roles in chemical and biological applications, e.g. adhesion of coatings, biofouling, and drug discovery, as well as energy sector, e.g. enhanced oil recovery and icing of wind turbines.

Given the above needs, accurate and facile measurement methods for contact angle, and surface tension, are required to enable R&D, quality control, or field tests. Drop shape analysis (DSA) using image processing and solution of Laplace equation (for pendant or sessile droplets, see Fig. 1) is the most popular measurement method.

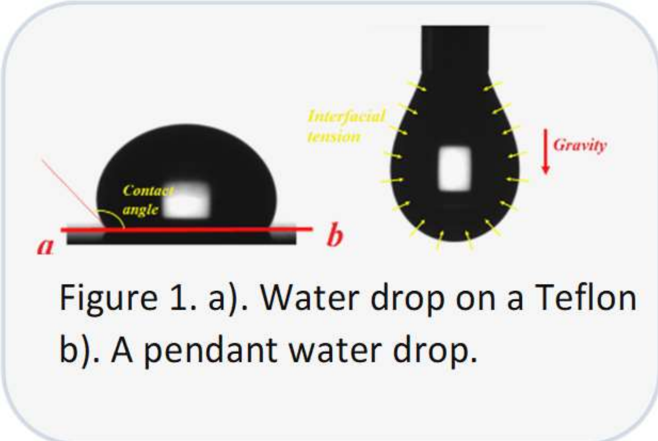

Figure 1. a). Water drop on a Teflon b). A pendant water drop.

The origins of the computerized DSA based tensiometry systems is in Canada, but many foreign manufacturers adopt the idea, and produced commercial instruments that up until recently was imported to Canada. However, this has changed in the past months as a spin-off company (Droplet Lab*) from the group of Prof. **Alidad Amirfazli** at Mechanical Engineering, York University, has been able to make the first smartphone based tensiometry systems (Dropometer) in Canada (see Fig. 2). The smartphone based DSA system is a first in the world that breaks the 40 years old design mold of the DSA systems that used bulky computers, camera, lens and a large chassis by taking advantage of smartphones. Dropometer is a compact and economical instrument that not only can be used for R&D, but also for educational purposes at undergraduate teaching labs (see Fig. 3).

The research that led to this innovation was funded by I2I program from NSERC as well as VISTA at York University. The published research that led to the spin-off shows that the accuracy is at 0.001% with ideal synthetic drop profiles. In another benchmark research published by the group at York, it was shown that the smartphone based DSA instrument matches the precision and accuracy of a foreign high-end commercial system for both contact angle and surface tension measurements. This story shows how funding for commercializing research results in labs at universities can help Canada to meet internal needs or even export instruments such as Dropometer, that now has been sold in Canada, USA, and China in a span of few months. Learn more: www.dropletlab.com

FIG. 3: DROPOMETER IS USED IN A CLASSROOM.

FIG. 2: SMARTPHONE MATED WITH A MODULAR HARDWARE THAT IS DESIGNED TO ALLOW VARIOUS MEASUREMENTS (E.G. SURFACE TENSION, CONTACT ANGLE, AND SLIDING ANGLE) BY INTERCHANGEABLY USING VARIOUS COMPONENTS. (LEFT) MANUAL VERSION; (RIGHT) AUTOMATED VERSION.

Dr. ALIDAD AMIRFAZLI, PhD, FEIC, FCSME

Dr. Amirfazli is a Professor at the York University in Toronto, Canada where he founded the Department of Mechanical Engineering in 2013. He formerly held the Canada Research Chair in Surface Engineering at the University of Alberta, Canada. Amirfazli has produced exciting results in wetting behavior of surfaces, drop adhesion and shedding, drop impact, icing, direct laser patterning of self assembled monolayers, super-hydrophobic surfaces, and related instrumentation for the filed of surface science. He has had more than 200 scientific contributions, many in prestigious peer reviewed journals; he has also given many invited talks at international level. He is the editor for the Advances in Colloid and Interface Science, *and an editorial board member for other journals. Dr. Amirfazli has been the recipient of the Martha Cook Piper Research prize, Petro-Canada Young Innovator Award, and Killam Annual Professorship. He is a Fellow of the Engineering Institute and Canada, and CSME. In 2014 he was inducted into the Royal Society of Canada's College of New Scholars, Artists and Scientists. He also served in the board of Professional Engineers of Alberta, and been a consultant with various companies in USA, Europe, and Canada.*

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ICAST

30th International Conference on Adaptive Structures and Technologies

The 30th International Conference on Adaptive Structures and Technologies (ICAST2019) will be held at Conference Center of Concordia University, Montreal, Canada from October 7th to 11th, 2019. This conference will be co-hosted by the National Research Council of Canada (NRC) and Concordia University.

ICAST2019 is the 30th event of the series of highly successful international conferences in the field of smart materials and adaptive structures and systems. This annual conference has been well attended by a diverse mix of international experts from both academia and industry in related fields of smart materials, adaptive structures, systems and solutions, tools and methodologies, as well as applications.

ICAST2019 aims at promoting research, development and applications of adaptive structures and technologies through exchange of scientific results and insights from leading scholars and specialists. The conference will serve as an international forum for promoting exchanges and discussions among experts on recent advances in the multidisciplinary field of smart materials and adaptive structures through oral as well as poster presentations.

The conference web site is available at: icast2019.encs.cononcordia.ca. The extended abstracts must be prepared using the given template and submit to the conference office via e-mail: icast2019@encs.concordia.ca before 1 May 2019. The abstract must be limited to two pages. Authors are encouraged to submit their full-length papers for consideration of publication in a special issue of the Journal of Intelligent Material Systems & Structures (JIMSS). Each manuscript must be uploaded on the journal website by 31 October 2019.

Important Dates:

- 1 May 2019: Extended Abstract Submission (Limited to 2 Pages)
- 1 June 2019: Notification on Acceptance
- 1 June - 1 August 2019: Early Bird Registration
- 7 - 11 October 2019: ICAST2019

We cordially invite you to ICAST2019 and look forward to meeting you in Montreal!

Conference General Chairs
Dr. **Ramin Sedaghati** (Concordia University) and Dr. **Yong Chen** (NRC)

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NEW FACULTY SPOTLIGHT SERIES:

FOCUS ON ONTARIO

This series highlights new Canadian ME faculty members by region.
In this spring issue, Ontario research highlights from:

Dr. **Amy Bilton**, University of Toronto; Dr. **Zahra K. Motamed**, McMaster University; Dr. **Eric Johlin**, Western University; Dr. **John Montesano**, University of Waterloo; and Dr. **Thomas Cooper** and Dr. **Roger Kempers**, York University

University of Toronto
Dr. Amy Bilton

Addressing pressing global challenges with efficient energy and water systems

UNIVERSITY OF TORONTO ASSISTANT PROFESSOR AMY BILTON IN THE WATER AND ENERGY RESEARCH LAB.

Amy Bilton was first exposed to the realities of poverty and global inequity at a young age. When she was a child, her family traveled internationally, including to Honduras and Belize in Central America. These experiences sparked Bilton's interest in and commitment to improving quality of life for the world's most vulnerable, and would shape her research direction and career path for years to come.

Bilton completed a Bachelor of Applied Science at the University of Toronto (U of T) with a focus on aerospace engineering, and received her Master's of Science in aeronautics and astronautics from the Massachusetts Institute of Technology (MIT). She then worked as a Systems Engineer at Pratt & Whitney Canada and Honeywell Aerospace. While she enjoyed the challenging projects, she started to feel a disconnect between her work and her passion for addressing the pressing issues in developing countries.

She decided to go back to school to pursue a PhD in aeronautics and astronautics with a focus on solar water desalination at MIT. Upon graduation in 2014, Bilton joined U of T's Department of Mechanical & Industrial Engineering as an Assistant Professor and Associate Director of the Centre for Global Engineering (CGEN). Now the Director of CGEN, Bilton oversees projects in communities around the globe including Bangladesh, Colombia, Vietnam, Kenya and Nicaragua.

CGEN partners with international and local partners to work on initiatives that focus on using energy in more effective ways to create positive change in communities. Today, Bilton's primary project is an aquaculture system that improves the water quality of fish ponds. She and her team of researchers and students tested the initial concept through modeling and optimization in her lab, the Water and Energy Research Laboratory (WERL). The technology uses solar energy in the form of heat to introduce more dissolved oxygen into the water. By introducing more dissolved oxygen, fish will grow faster and convert food to body mass more efficiently. The goal is to encourage healthier fish and better fish yields for local farmers. After years of testing and prototyping, they are now starting to gather results from the field.

Bilton oversees 12 projects around the world that include international partners such as Environment Canada, World Vision and Winds of Change. Most of the partnerships originate when the organization presents an important problem to Bilton and her group, and they assess whether and how they can address it.

The WERL lab is a bustling hub of students and researchers developing innovative technologies and design methods for more efficient energy and water systems. There are often suitcases tucked under desks and benches, as members of the group frequently travel around the world to implement the projects they create and test in the lab — Bilton herself has now travelled to over 60 countries. She credits those early family trips with sparking her passion for applying engineering design and innovation to engender positive change in communities around the world.

BILTON AND GRADUATE STUDENT SACHA RUZZANTE ATTACH SENSORS TO A SOLAR AERATION PROTOTYPE FOR SMALL-SCALE AQUACULTURE IN MYMENSINGH, BANGLADESH, 2017.

Dr. AMY BILTON, PhD, MCSME

Dr. Bilton joined the Department of Mechanical & Industrial Engineering at the University of Toronto as an Assistant Professor in January 2014. She completed her BASc at U of T in Engineering Science (aerospace option) and her MS at the Massachusetts Institute of Technology in aeronautics and astronautics. After completing her MS, Bilton worked as a Systems Engineer at Pratt & Whitney Canada and Honeywell Aerospace. She then returned to MIT where she completed her PhD in aeronautics and astronautics and continued as a postdoctoral associate

Bilton is the Director of the Centre for Global Engineering and leads the Water and Energy Research Laboratory. Her research lies at the intersection of developing theoretical design and control techniques and developing new physical electromechanical systems. Applications of her research include water purification systems, desalination systems, and renewable energy. Her current work is focused on deployment of a newly developed solar-powered water purification system in the developing world.

PHOTO TOP RIGHT: PAM WALLS / UNIVERSITY OF TORONTO

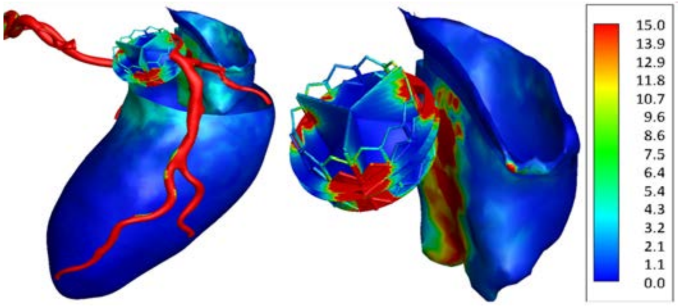


FIG. 1: TIME-AVERAGED WALL SHEAR STRESS (IN PA) IN THE VENTRICLE OF A PATIENT WHO RECEIVED TRANSCATHETER AORTIC VALVE.

McMaster University
Dr. Zahra K. Motamed

Development of diagnostic and predictive computational mechanics methods for cardiovascular disease

Cardiovascular disease is the leading cause of death globally, taking more lives than all forms of cancer combined. It is expected to remain the first cause of death by 2030 in the world. In Canada, one in every four deaths is from cardiovascular disease. Cardiovascular disease is the leading cause of burden on healthcare around the world and costs the Canadian economy more than $22 billion every year.

Despite advancements in surgical/interventional techniques, many cardiovascular patients do not respond favorably to treatments and their life expectancy remains reduced. Abnormal hemodynamics and biomechanics lay at the base of the initiation and progression of many cardiovascular diseases. Blood flow quantification can be greatly useful for accurate and early diagnosis of cardiovascular diseases. However, the fluid-dynamics methods that can be used as calculating engines of the new diagnostic tools are yet to be developed. Furthermore, as most interventions intend to restore the healthy condition, the ability to predict hemodynamics and biomechanics resulting from a particular intervention has significant impacts on saving lives. Predictive methods are rare. They are extensions of diagnostic methods enabling prediction of effectiveness of interventions, allowing systematic testing for possible clinical solutions, and thus enabling personalization of interventions. Advancing computational mechanics offers a powerful means to augment clinical measurements and medical imaging to create non-invasive diagnostic and predictive tools. This is the aim behind a computational cardiovascular mechanics framework that Dr. Motamed's lab is developing.

Dr. Motamed's research interests are in the areas of translational and basic cardiovascular mechanics. Using multidisciplinary research, she and her team try to advance knowledge in biomechanics, fluid mechanics, solid mechanics, medical imaging and mathematical modelling. A major part of her work has been dedicated to development and validation of advanced multi-scale computational-mechanics and imaging-based algorithms for patient-specific modelling of cardiovascular system with the following objectives:

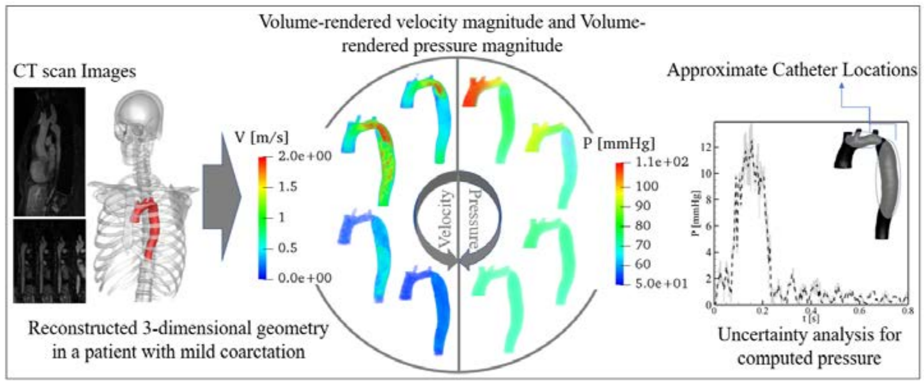
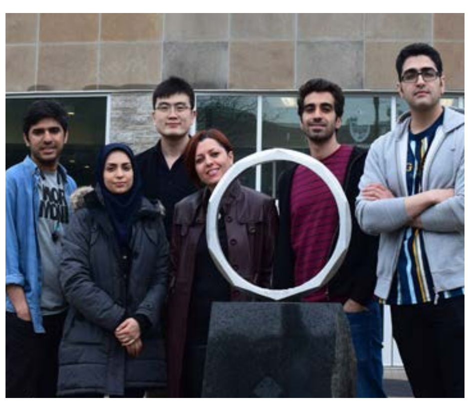


FIG. 2: PIPELINE FOR GEOMETRY RECONSTRUCTION, COMPUTATIONAL SETUP AND FLUID DYNAMICS SIMULATION USING LATTICE BOLTZMANN METHOD IN A PATIENT WITH COARCTATION OF THE AORTA.

- To develop long needed quantitative diagnostic, predictive and intervention-optimization tools for cardiovascular diseases to support personalized interventions and clinical decision making;
- To design, evaluate and optimize cardiovascular devices such as transcatheter heart valves and vascular stents;
- To uncover causes of cardiovascular pathologies through solving complex biomedical problems;
- To lead multidisciplinary collaborative efforts to translate engineering-based findings and developments into clinical practice.

DR. MOTAMED AND HER LAB MEMBERS.



Dr. ZAHRA K. MOTAMED, PhD

Dr. Motamed is an Assistant Professor in the Department of Mechanical Engineering at McMaster University. She also is a research affiliate faculty member in the Institute for Medical Engineering & Science at MIT (Cambridge, MA). Before joining McMaster, she was a postdoctoral fellow at Harvard-MIT Biomedical Engineering Center at MIT. She received her PhD degree in mechanical engineering from Concordia University. Her research interests are in the areas of translational and basic cardiovascular mechanics to develop long needed quantitative diagnostic, predictive and intervention-optimization tools for cardiovascular diseases to support personalized interventions and clinical decision making. She also has eight years of industrial experience in the R&D sector with a proven record of leadership and project and team management.

IMAGES COURTESY OF THE RESEARCHER

Western University
Dr. Eric Johlin
Algorithmic design of nanophotonic structures

Nanophotonics is the study of interactions between light and materials with structural elements of sizes comparable to optical wavelengths. At these length scales, the wave nature of light begins to control the interactions, leading to the emergence of phenomena which would appear unintuitive at the macroscopic length scales we interact with in our daily lives. These phenomena can also be highly advantageous from a device standpoint, for example allowing the creation of optical antennas that can absorb light from areas beyond their physical cross section; cavities which hold (and allow interactions with) photons for millions of cycles; and lenses that are able to tune the spectral and spatial distribution of emission and absorption.

Despite the potential benefits to these interactions, the utilization of such nanophotonic features, particularly in 3D structures, has been quite limited. This is due to two factors – first, and most obviously the difficulty in producing such structures, and second, the difficulty in their design. The former has been substantially addressed in recent years, with the emergence of 3D nanolithography, improved techniques for self-assembly, and nanoscale holography. The design challenge however still remains, and the same unintuitive phenomena that permit the enhanced functionality of nanophotonic structures also make traditional intuition-based design inherently unsuited to the challenge. Dr. Johlin and his group are working to address this, exploring the use of algorithmic design (allowing the structure to be completely determined by a computer algorithm) for the creation of 3D nanophotonic structures.

An example of this process was applied to the creation of a nanophotonic lens (nanolens) for controlling the emission of the luminescence from a gallium arsenide nanowire. These nanowires are used in creating nanoscale solar cells, lasers, and light emitting diodes, however their angular emission and absorption response is not ideal. An evolutionary algorithm, coupled to finite-difference time-domain simulations of the performance of the evolving structure (shown in *Fig. a*), was used to design the nanolens, as depicted in *Fig. b*. Simulations indicated that this nanolens structure is able to control the angular response of optical interactions with the nanowire more than three times better that of traditionally-designed lenses of the same size. The algorithmically-designed nanolens structures were then experimentally fabricated (*Fig. c*) using two-photon absorption lithography to print the 3D structures out of low index dielectric (glass-like) material, directly on top of nanowires. Simulations of the experimental conditions were then employed to allow the measured angular emission spectra to be understood as resulting from a slight mis-alignment between the nanowire and nanolens. This work was recently published in *Nature Communications*, Vol. 9, pg. 4742.

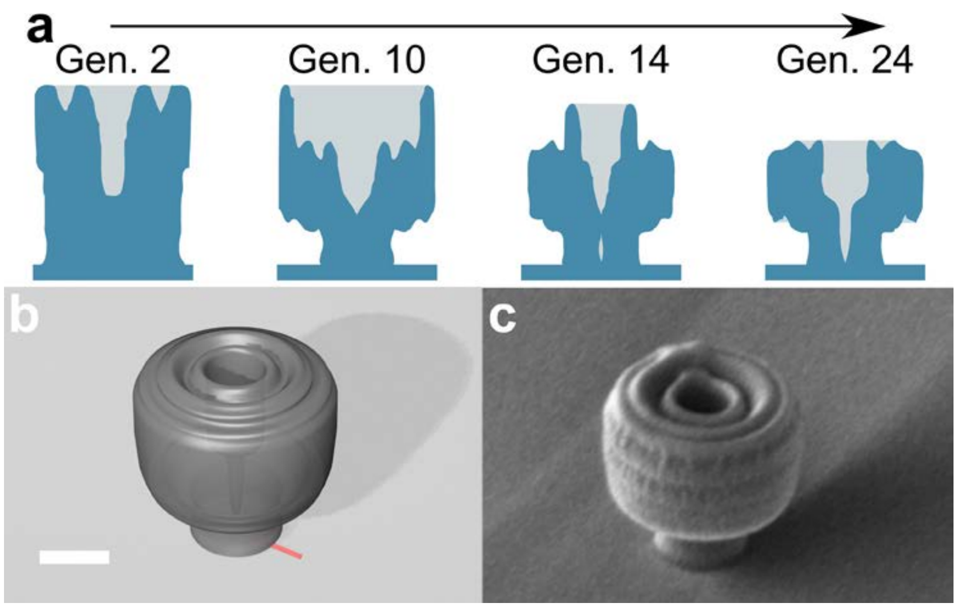


FIG. A: PROGRESS OF EVOLUTIONARY ALGORITHM DESIGNING THE NANOLENS CROSS-SECTION; FIG. B: COMPUTER RENDERING OF FINAL DESIGN, COMPARED TO FIG. C: SCANNING ELECTRON MICROSCOPE IMAGE OF THE FABRICATED STRUCTURE. WHITE SCALE BAR (B) IS 2 MICRONS.

Dr. Johlin's lab is currently working on extending the processes of algorithmic design of nanophotonic components – expanding the number of degrees of freedom the algorithms can reasonably use in design, as well as exploring new applications where such design processes can both improve performance and even provide new functionality to devices. Furthermore, the lab is investigating ways to improve the techniques supporting the fabrication of such 3D nanophotonic structures, as well as the characterization of devices utilizing them. The group is also working to improve the fundamental understanding of tradeoffs between optical properties and to discover the limits to which nanostructuring can improve these properties.

For more information, visit the group at www.eng.uwo.ca/nem.

Dr. ERIC JOHLIN, PhD

Dr. Johlin is an Assistant Professor in the Department of Mechanical and Materials Engineering at Western University. His group explores new structures, materials, and systems which utilize nanophotonic effects for optoelectronic applications. This work combines theory, simulations, and experiments to develop new devices and techniques, as well as improving the fundamental understanding of light-matter interactions at the nanoscale. Before coming to Western, Dr. Johlin was a postdoctoral researcher at the Dutch national laboratory AMOLF, in the Center for Nanophotonics. There, he worked on measurements and designs of nanostructured solar cells. He obtained his master's and doctoral degrees from the Massachusetts Institute of Technology (MIT), investigating the atomic structure of hydrogenated amorphous silicon, and the implications of this structure on the performance of photovoltaics.

IMAGES COURTESY OF WESTERN ENGINEERING

University of Waterloo
Dr. John Montesano

Multiscale Assessment of high-performance composite materials for wind turbines

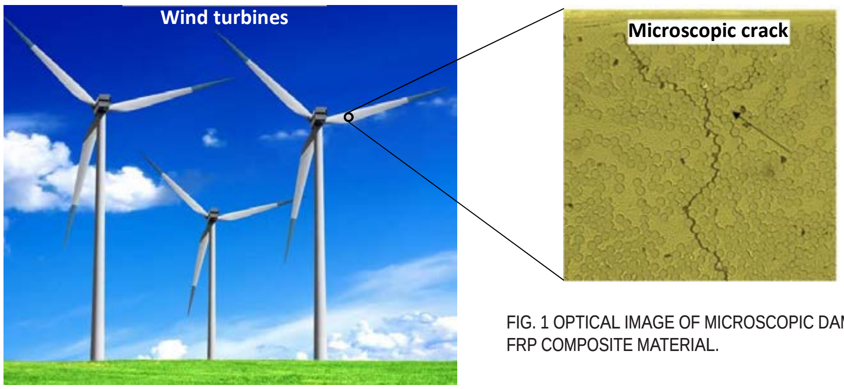


FIG. 1 OPTICAL IMAGE OF MICROSCOPIC DAMAGE IN FRP COMPOSITE MATERIAL.

Dr. JOHN MONTESANO, PhD, P.Eng.

Dr. Montesano is an Assistant Professor in the Department of Mechanical & Mechatronics Engineering at the University of Waterloo and Director of the Composites Research Group (CRG). His group focuses on multi-scale mechanics of fiber-reinforced composite materials and structures for various applications. Prior to joining Waterloo, he was an NSERC postdoctoral researcher in the Department of Materials Science at the University of Toronto, where he developed multiscale computational models for predicting failure of lightweight composite materials and structures. He received his PhD in aerospace engineering at Ryerson University in 2012, where he studied the long-term durability of composite materials. He also has more than five years of industrial experience working as a mechanical designer and structural analyst.

IMAGES COURTESY OF THE RESEARCHER

The motivation to reduce green house gas emissions continues to be paramount for addressing current global environmental and related energy efficiency concerns. In the automotive and aerospace sectors where fossil fuels are combusted to provide power for transportation, the direct benefits of developing lightweight low-emission or no-emission vehicle structures are clear. In the energy sector, the expanding reliance on clean renewable energy can significantly contribute towards addressing these climate change concerns. Specifically, wind power is a sustainable and relatively inexpensive renewable energy source which has been growing rapidly during the last decade. As a result of increased demand, there is a need to increase the power harvesting capacity of individual wind turbines and further reduce fuel dependence. The most effective approach is to increase the rotating blade length; however, this poses a challenge since increasing the blade length results in increased gravitational loading which significantly increases the demand on the structure thus impacting its useful service life. Therefore, it is imperative to minimize the weight of new wind turbine blade structures through design optimization and material selection, while simultaneously improving their durability to maximize lifecycle.

High-performance fiber-reinforced plastic (FRP) composite materials are gaining wider acceptance in the wind energy sector due to their high specific strengths and the ability to tailor the performance of corresponding structures. Heterogeneous and orthotropic FRP materials are also inherently damage tolerant, where various damage modes typically initiate as undetectable sub-critical microscopic cracks (see Figure 1; Nikforooz M, Montesano J, Golzar M, Shokrieh MM. *Composites Part B* (2019), Vol 161, pp 344-356) and progress into more critical damage modes which may lead to catastrophic failure. For wind turbine blades which are subjected to combined cyclic aerodynamic, centrifugal and gravitational loads the scenario can be quite complex. Therefore, the main challenge lies in better understanding and predicting the multiscale nature of these failure processes as well as their influence on the blade stiffness and performance.

Dr. Montesano's research group utilizes both experimental and computational techniques to assess the response of FRP composite materials and structures subjected to various loading conditions. With regards to experimentation, the focus lies on characterizing the progressive nature of different damage mechanisms in FRP materials using various non-destructive evaluation techniques (e.g., infrared thermography and light microscopy) and assessing the corresponding influence on performance. They recently produced, for the first time, damage

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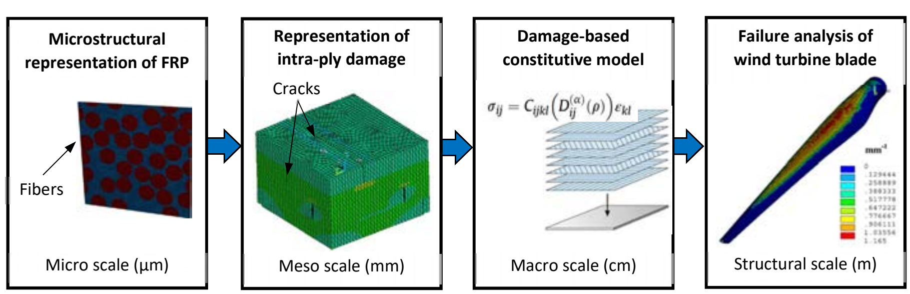

FIG. 2: DAMAGE-BASED MULTISCALE MODELING APPROACH.

York University
Dr. Thomas Cooper

Heat, clean-water, electricity and fuels from the sun

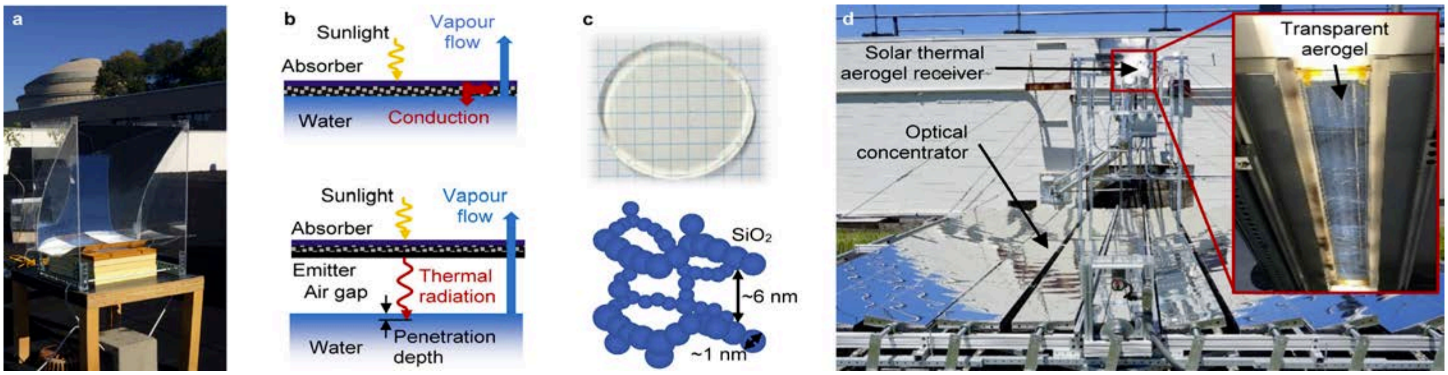

FIG. 1: SOLAR THERMAL TECHNOLOGIES TRANSFORM SUNLIGHT INTO HEAT, AND THEN INTO OTHER USEFUL PRODUCTS: (A) CONTACTLESS SOLAR EVAPORATION STRUCTURE PRODUCING CLEAN VAPOUR AT 140°C ON AN OCTOBER DAY IN CAMBRIDGE, MA. (B) SCHEMATIC OF CONVENTIONAL CONTACT SOLAR EVAPORATOR (TOP) AND THE CONTACTLESS CONFIGURATION (BOTTOM) WHICH CIRCUMVENTS THE FOULING PROBLEM. (C) TRANSPARENT NANOPOROUS SILICA AEROGEL AND ITS NANOSTRUCTURE. D) SOLAR THERMAL AEROGEL RECEIVER UTILIZING TRANSPARENT NANOPOROUS SILICA AEROGEL TO TRAP SUNLIGHT AS HEAT AT TEMPERATURES UP TO 400°C AND BEYOND.

Dr. THOMAS COOPER, *DrSc*

Dr. Cooper is an Assistant Professor in the Mechanical Engineering Department at York University. His research unites the fields of thermal science, materials, and optics to develop new pathways, devices, and systems to convert solar energy into useful forms. Before joining York University in July 2018, Dr. Cooper was a postdoctoral associate at MIT in the NanoEngineering Group led by Prof. Gang Chen, where he worked on solar energy harvesting technologies enabled by materials with tailored optical and thermal properties. Dr. Cooper received his BASc from the University of Toronto in 2008 and his MSc and DrSc from ETH Zurich in 2010 and 2014, respectively. He received the ASME Solar Energy Graduate Student Award, the ETH Medal, the Hans Eggenberger Prize, and the Chorafas Prize for his work on low-cost solar energy technologies.

The sun provides a virtually inexhaustible source of renewable energy to our planet, with enough solar energy reaching the earth a single hour exceeding the total yearly global energy demand. For many, the term solar energy is synonymous with the familiar "solar panels" that directly convert sunlight into electricity via the photovoltaic effect. However, solar energy can be converted into many other useful forms via different conversion processes. The research of the CooperLab is focused on solar thermal technologies, where sunlight is converted into heat (thermal energy), and subsequently into other useful forms. Temperatures spanning 100°C to 2000°C can be realized, supporting a wide range of downstream processes from space heating to water splitting. This article touches on four aspects of Dr. Cooper's research in solar thermal energy conversion, starting from the low temperature and working up to the high temperature regime. A common theme is how new materials, or leveraging old materials in new and creative ways, can enable new systems to convert solar energy into useful forms.

Providing access to clean drinking water is one of the grand challenges currently facing our planet, to which solar-driven desalination provides an accessible, equitable, and low-cost solution. Structures made from photothermal materials can be floated on bodies of salt-water where they absorb sunlight as heat and transfer it to the water surface to produce clean vapour, which can be condensed into clean drinking water. A critical challenge is that the salts and impurities left behind during the evaporation process can clog, contaminate, and foul the photothermal structure. During his postdoc at MIT, Dr. Cooper developed a contactless solar evaporation structure (CSES) which does not need to contact the water, thus avoiding the fouling problem entirely. The CSES is suspended above the water, absorbing solar photons and down-converting them to infrared photons which are directly absorbed within a sub 100 micrometer depth in the water layer beneath (panels A and B of the figure above). In addition to the physical separation, thermal separation between the absorber and the water allows the vapour to be superheated to temperatures exceeding 140°C, making the vapour useful for sterilization, cleaning, and cooking, in addition to being a source of clean water. The results of the research are published in *Nature Communications*, vol. 9, article no. 5086.

Increased temperatures open the door to new applications. Yet the achievable temperature of flat solar collectors is limited by the dilute nature of solar energy, with a peak flux of roughly 1 kW/m^2. Compare this to the flux of electrical power passing through the cord of a toaster of 5×10^5 kW/m^2, or to the heating value flux passing through a gas pump nozzle when fueling a car of 5×10^7 kW/m^2. The dilute nature of sunlight can be overcome by optical concentration. Reminiscent of the childhood experiment of burning a leaf with a magnifying glass, concentrating solar technologies use mirrors to focus incident sunlight onto a small focal spot or focal line to significantly increase the energy flux, in theory up to 46,000 times. Traditional solar concentrators rely on expensive precision

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PHOTO (COOPER): COURTESY OF THE LASSONDE SCHOOL OF ENGINEERING, YORK UNIVERSITY / IMAGES COURTESY OF THE RESEARCHER

York University
Dr. Roger Kempers

Creating a New Generation of Additively Manufactured Heat Exchange Technologies

By a large margin, most energy transport and conversion on our planet occurs via heat transfer: hydrocarbons, nuclear fuel, and solar thermal radiation, for example, are all converted to heat to produce mechanical work for ultimate use in electricity generation or locomotion. From a technology standpoint, the physical energy interface between the ecosystem in which we live and everything from power plants to data-centers, satellites to mobile phones, is the heat exchanger. As such, there are tens of billions of heat exchangers on and around our planet which makes them the most ubiquitous physical energy interfaces. Even so, the heat exchanger has not evolved at anywhere near the same pace as other technologies such as electronics, automotive, computer, aerospace, biotech, textile, etc. Oftentimes, the modern heat exchanger is still no more than a piece of metal designed upon fundamental research performed over half a century ago. This should not be the case.

The over-arching vision of the research program at TF-LAB is to position heat transport, exchange and management at the leading edge of energy research where it belongs. This is being accomplished through the development of a multi-disciplined thermofluids research program which combines classical thermal-fluid science with materials science, advanced manufacturing, fluid control strategies, measurement techniques, design theories and optimization strategies. Together, this will support the development of improved heat transfer technologies that can help address the thermal issues that contribute to the world's energy challenges.

One key research area at TF-LAB stems from the confluence of additive manufacturing and heat transfer. Additive manufacturing (AM) of either polymer composites (PC) or metals, can offer the creation of complex surface morphologies, internal geometries and structures with unprecedented surface area-to-volume ratios. This opens the door to exciting new heat exchanger design opportunities and represents a new frontier in heat exchanger design and fabrication. In addition, AM affords unique approaches for the fabrication of high conductivity PCs for heat transfer applications. It presents an exciting opportunity to leverage the potential of both the exceptional material properties offered by PCs and the unique fabrication possibilities offered by AM approaches. The objectives of the research are to further develop AM–PC fabrication technologies and to develop a fundamental understanding of thermal transport mechanisms within and from AM–PC and metal solids and structures as they relate to the engineering of next generation high-performance heat transfer technologies.

Researchers at TF-LAB have developed a novel 3D printing approach whereby continuous metal wires are co-extruded along with a thermoplastic to allow for the fabrication of continuous wire polymer composites (CWPC) which offer significantly higher effective thermal conductivities than their discontinuous composite counterparts. Moreover, 3D printing allows the directionality of the conductive pathways to be designed and tuned for a given application. This fabrication approach has also spawned other research into configurable 3D printed heater elements and 3D printed sensing elements (strain, pressure, and heat flux) for integrated structural health monitoring applications.

More recently, this process has been adapted to print high-conductivity pitch-based continuous carbon fibre polymer composites (CFPCs). Pitch-based carbon fibres have a very high thermal conductivity (800 W/mK) but are very brittle under shear. To ensure fibre continuity during the printing process, the fibres are pre-coated with molten polymer using a pultrusion setup. The printer head and extrusion nozzle were designed to minimize sharp bend angles on the fibre, allowing for the printing of unidirectional raster samples as shown in Fig. 1). A cross-section of the coated filaments is also shown. Initial pitch-based 3D printed CFPCs exhibit thermal conductivities of up to 60 W/mK.

Future work in this area will address the fabrication of more complex components and topologies will be accomplished by developing a controllable rotating print bed coupled with the angled extruder, which will also allow for directional control of the continuous fibres within the printed component and allow for the development of components with customizable regions of conductivity and variable anisotropy. Subsequent development will further allow for the fabrication of AM–CFPCs using high temperature thermoplastics such as polyetherimide (PEI) and polyether ether ketone (PEEK).

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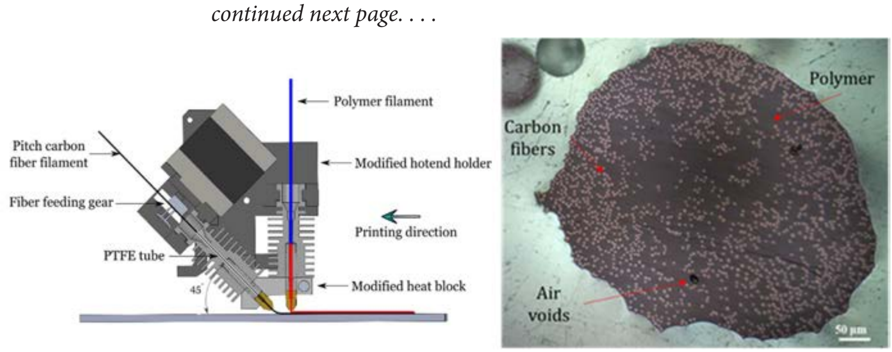
Dr. ROGER KEMPERS, PhD, P.Eng.

Dr. Roger Kempers is an Assistant Professor in the Department of Mechanical Engineering at York University. He earned a B.Eng. & Society (Mechanical) in 2002 and an MASc (Mechanical) in 2004 from McMaster University, Hamilton, Canada. He completed his PhD in Mechanical Engineering at Trinity College Dublin, Ireland, in 2010.

Prior to joining York, Dr. Kempers was a Distinguished Member of Technical Staff at Nokia (formerly Alcatel-Lucent) where he led the R&D of advanced thermal management technologies for wireless telecommunications hardware. Previously, Dr. Kempers worked as a Research Engineer at Lucent Technologies, Bell Labs Ireland, where his activities ranged from fundamental heat transfer research to thermal technology development, licensing, and product integration. In this capacity he developed two-phase cooling architectures for remote radio head products. He was also responsible for the development and implementation of novel metal micro-textured thermal interface materials which reduced component temperatures in several key products.

Dr. Kempers is the founding director of the Advanced Thermofluids & Heat Transfer Research Lab (www.tf-lab.ca) in the Department of Mechanical Engineering at York University. His research interests lie primarily in thermal-fluid sciences and are multi-disciplined in nature, geared toward the advancement of heat transport, exchange, and conversion technologies to help address industrial thermal energy challenges. He is particularly interested in the confluence of two-phase heat transfer with additive manufacturing to further the development of heat exchange technologies.



(a) (b)

FIG. 1: (A) CONTINUOUS FIBRE PRINTING MECHANISM FOR HIGH-CONDUCTIVITY PITCH CARBON FIBRES; (B) CROSS SECTION OF A PRE-COATED PITCH-CARBON FIBRE FILAMENT.

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Faculty Spotlight continued from page 21

Other research in our lab has led to the development of an enhanced transient plane source (TPS) technique which can characterize the anisotropic thermal conductivities of materials without requiring additional thermal capacitance measurements.

Finally, a research project investigating the boiling heat transfer on AM surfaces (PC and metal) is underway. A pool boiling apparatus has been designed and constructed which facilitates boiling of low GWP fluids that are being considered for, among other things, electronics cooling and waste heat recovery. These are generally low boiling point fluids which are ideal for use with AM-PCs. The AM-CFPCs discussed above, or metal AM approaches such as direct metal laser sintering will allow for the local variation of surface wettability, porosity, nucleation site density, and site distribution. Surface structures such as re-entrant cavities, pillars, posts, and micro-grooves will be investigated to understand their influence on boiling heat transfer coefficient and CHF.

Applied research in this area centres around the development of novel two-phase heat transport loops such as thermosyphons and lightweight vapour chamber heat sinks for a wide range of industrial thermal management applications.

The aim of this research is to yield a comprehensive understanding of the important heat transfer mechanisms and phenomena associated with AM–PCs, develop new theoretical models for predicting and designing AM heat exchange components, and constitute a significant step forward towards the realization of a new generation of compact, high-performance, and lightweight heat transport, exchange, and conversion technologies.

THE CANADIAN SOCIETY FOR MECHANICAL ENGINEERING
LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE

Honours & Fellowships 2019

Robert W. Angus Medal
Dr. Markus Bussmann, FCSME, University of Toronto

C.N. Downing Award
Dr. Aleksander Czekanski, FCSME, York University

G.H. Duggan Medal
Dr. Daolun Chen, MCSME, Ryerson University

Jules Stachiewicz Medal
Dr. Yuri Muzychka, FCSME, Memorial University of Newfoundland

Fellows
Dr. Seth Dworkin, FCSME, Ryerson University
Dr. Yuping He, FCSME, Ontario Tech University
Dr. Xinyu Liu, FCSME, University of Toronto

International Recognitions Awarded to Members

Dr. Muthukumaran Packirisamy, FCSME (2009) of Concordia University, was elected Fellow of the National Academy of Inventors (NAI). He is one of only 11 Canadians to be so honoured since the inception of the society in 2010.

Chair's Corner continued from page 6

FPC has strengthened the research of numerous MME researchers by being able to attract large funded projects that could not otherwise be considered. The centre houses equipment that does not exist for research and trial elsewhere in Canada. The connection with Fraunhofer has also strengthened the connection between the Karlsruhe Institute of Technology and Western leading to research exchanges, and the development of an advanced manufacturing course. The centre is also closely connected with the International Composites Research Center (ICRC) and to Surface Science Western and the Centre for Advanced Materials and Biomaterials Research (CAMBR), which brings together more than 50 research groups to tackle key materials challenges.

Western in collaboration with London health Sciences Centre and its affiliate institutes is a Canadian mecca for musculoskeletal research, and the MME department leads some of the most prolific groups and centers. The Hand and Upper Limb Centre (HULC), an internationally renowned centre in upper-extremity biomechanical research, is co-directed by MME Prof. J. Johnson and serves as an archetype in biomedical engineering. This centre was developed more than 25 years ago and combines medical and engineering research to study implantation and surgical techniques. The center is renowned for its ground-breaking research in shoulder and elbow biomechanics and on shoulder arthroplasty, which has had a profound impact on the implant industry. In addition, research into tissue/tendon and ligament repair have resulted in significant changes in a surgeon's management of elbow disorders. Other biomechanics researchers in MME include a CRC Tier 2 Chair in Craniofacial biomechanics, and four others who conduct research on surgical techniques, implants, joint wear, sport and gait, and rehabilitation.

Western MME also has critical strength in fundamental and applied thermofluids, where researchers tackle fundamental problems in hydrodynamics and heat transfer of single and multiphase systems. Basic theoretical research in hydrodynamic stability and smart surfaces is done with application to drag reduction and enhanced heat transfer. The development of computational algorithms and physical models for porous materials and heat and mass exchange with application to energy capture and storage are also key areas of study. Researchers in the thermofluids group also use a low-disturbance wind tunnel to study fundamental fluid mechanics including convective patterns and initiation of turbulence in boundary layer flows. The world-renowned Boundary Layer Wind Tunnel facility and the recently constructed WINDEEE laboratory provide facilities for large-scale study of atmospheric boundary layers and downbursts, which are of interest for studying the effects of storm and wind damage.

In all, Western MME offers unique undergraduate programming that enables students to customize their studies with other degree options and experiential learning opportunities, and graduate opportunities to conduct world-class research in an intensive and stimulating environment.

CSME STUDENT CHAPTER
REPORT

The student chapter report is compiled from the CSME student chapter event reports composed by the respective CMSE student chapter executives.

CSME CONCORDIA
STUDENT CHAPTER MEMBERS, ORGANIZING TEAM AND CURRENT EMPLOYEES AT THE PLANT TOUR IN LACHINE, QUÉBEC.

THE PAST ACADEMIC YEAR HAS BEEN FULL OF exciting events and activities led by the CSME student chapters. Chapters have engaged current undergraduate students in industry networking events, facility tours, design competitions and industry guest lectures.

The CSME Concordia chapter organized an industry plant tour of Current. Current is a Montreal LED lighting company powered by GE and located in Lachine, Québec. Current blends LED lighting and digital networks to make commercial buildings and industrial facilities more energy efficient and productive. The students had the opportunity to follow some of the lighting manufacturing processes, which included additive manufacturing, CAD designing, electrical assembly of circuits and electrical and mechanical testing of assembled products. Students saw first-hand how the design and development of LED lighting is done and how lights are tested. Participants also interacted with the multiple interdisciplinary departments and experienced how they work together to create the final products. Current generously provided food to everyone in attendance. Current's team was impressed by the CSME Concordia chapter members in-depth questions and background knowledge on manufacturing for lighting. More photos can be found at their Facebook page (www.facebook.com/csmeconcordia).

The CSME uOttawa chapter organized their inaugural networking event 'A Night with NRC and CSME' in February. The goal was to promote different collaborations among CSME, professors, industry professionals, undergraduate and graduate students. The event was hosted in partnership with the University of Ottawa's Co-op Services and Careers and sponsored by the Undergraduate Research Opportunity Program (UROP) and the Canadian Society for Mechanical Engineering (CSME). Approximately 100 people attended the event.

This event included a panel of researchers from the National Research Council (NRC) and CSME to present projects, share ideas, and network with undergraduate and graduate students of the Faculty. It was a great event for students to network with professionals, and an incredible opportunity for professors, CSME, NRC, NRCan, CAE Inc and other industry professionals to exchange, share project ideas and information. Co-op Services and Careers provided priceless professional services including the 'Let's talk careers!' kiosk with information on the career development centre, LinkedIn profile photoshoots and resumés and LinkedIn profile reviews.

The evening commenced with a brief introductory speech by the vice presidents, Nour and Ferly, followed by individual guest speakers who discussed their research projects: Dr. Faizul Mohee, Dr. Michal Bartko, Dr. Michael Jakubinek, Dr. Taylor Robertson and Dr. Marina Freire-Gormaly. The uOttawa CSME chapter president, Amro Ahmed, gave closing remarks and thanks. The final portion of the event consisted of a networking period over classical music played by 'Flames of Pluto' and guests enjoyed food and refreshments. NRC also provided a prototype of sustainable mining research work so students could learn more about their work. The golden sponsor Talluza, also supplied Arabic desserts that everyone enjoyed. Students also presented their research project posters during the networking session. A few weeks after the event, Dr. Michal Bartko provided a tour of the NRC Construction Lab for the uOttawa and Carleton students. More photos and events from CSME uOttawa can be found at their Facebook page (www.facebook.com/uOttawaCSME).

At the CSME British Columbia Institute of Technology (BCIT) chapter, they hosted their annual industry-student night. Multiple companies were in attendance and students were able to learn about the exciting work in the local industry and make meaningful connections. Further events and photos from CSME BCIT chapter can be found at their Facebook page (www.facebook.com/BCITSACSME).

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CSME uOTTAWA
CSME uOTTAWA CHAPTER PARTICIPANTS OF THEIR 'A NIGHT WITH NRC AND CSME' INCLUDING PROF. NATALIE BADDOUR, CHAIR OF MECHANICAL ENGINEERING, GUEST SPEAKERS, ORGANIZING COMMITTEE AND ATTENDEES.

CSME uOTTAWA AND CSME CARLETON
CHAPTER MEMBERS WITH DR. MICHAL BARTKO AT THE NRC CONSTRUCTION LAB TOUR.

PHOTOS COURTESY OF THE CSME STUDENT CHAPTERS

CSME BCIT
PHOTO RIGHT: **CHAPTER MEMBERS, INDUSTRY PROFESSIONALS AND STUDENTS AT THEIR BCIT PROFESSIONAL NIGHT 2019.**

We are also encouraging CSME student chapters to participate in the CSME congress this June. We will have a workshop to facilitate new events, lessons learned and inter-institutional collaboration for future events. Come meet members of CSME chapters from across Canada! The CSME National Design competition will also be held at the upcoming CSME congress. We're looking forward to all the projects and papers being presented at Western University in London, Ontario.

Please join us as a CSME member — it is FREE for students (csme-scgm.ca/application). The Engineering Careers site (www.engineeringcareers.ca) also provides an opportunity to plan for your career. We are also looking forward to a CSME internship program for students to participate in industry.

Thank you to all the student chapter executives, volunteers and faculty mentors for your hard work! If you're interested in leading and founding a CSME student chapter at your campus, let us know. Contact us at m.freire.gormaly@utoronto.ca or faizul.mohee@utoronto.ca or the CSME directly and we will walk you through the process. We're also looking to expand the CSME Student Affairs Committee. If you're interested in helping organize activities at the national level, please reach out.

Do you have a great idea, story or proposal to improve the CSME student programming? Feel free to share your ideas with us!

CSME uOTTAWA
PHOTO LOWER LEFT: **WILL RENDER (NRC), NOUR DOWEDAR (CSME uOTTAWA VP INTERNAL), DEVAN MCDONALD (NRC), AND KEN JUDGE (NRC TEAM LEADER) WITH A ROCK BOLT TESTING APPARATUS ON THE RIGHT.**

CSME uOTTAWA
PHOTO ABOVE RIGHT: **DR. MICHAL BARTKO (NRC CONSTRUCTION RESEARCH CENTRE) WITH AMRO AHMED, CSME uOTTAWA CHAPTER PRESIDENT AND DR. TAYLOR ROBERTSON (NRC AEROSPACE RESEARCH CENTRE).**

PHOTO RIGHT: **PRESENTATION BY DR. MICHAEL JAKUBINEK, (NRC EMERGING TECHNOLOGY).**

Did you know CSME student membership is FREE?

csme-scgm.ca/application

DR. MARINA FREIRE-GORMALY, PhD, EIT, LEED GA, SCMSE,
Chair of CSME Student Affairs
Marina is looking forward to starting this summer as an assistant professor at York University in Mechanical Engineering. She is currently a postdoctoral fellow at the University of Toronto. She completed her PhD at the University of Toronto in the Department of Mechanical & Industrial Engineering. She is excited to continue her research and teaching on energy systems, nuclear, computational modelling and sustainability at York.

DR. FAIZUL M. MOHEE, PhD, P.Eng., PMP
Vice Chair of CSME Student Affairs
Faizul is the lead structural and materials engineer at TMBN Extrados Inc. in Toronto. He completed his PhD at the University of Waterloo on mechanical anchors for composite materials. He also did a master's at the University of Toronto. He taught the Materials Science course at U of T in the Department of Mechanical & Industrial Engineering. He previously worked at Hatch, WSP and projects for OPG, Bruce Power, Terrestrial Energy, Baffinland, Stornoway, SaskPower and Emera. Faizul works in research and development for the energy, mining and nuclear industries. He is passionate about research, teaching and student engagement to build smart and sustainable infrastructure resilient and adaptive to climate change.

PHOTOS COURTESY OF THE CSME STUDENT CHAPTERS / ILLUSTRATION BY SHUTTERSTOCK

Wind energy continued from page 10

flying kite. The analytical models will also continue to become more reliable by improving the underlying theories. On a different level, we at Concordia University are closely collaborating with New Leaf Ltd. and the University of Victoria to launch a national initiative for accelerating the development and raising the commercial deployment readiness level of such technology, by deploying a fully autonomous low- to mid-scale CKPS in the short term (1 to 2 years) and by scaling up to an offshore demonstration in the long term (5 to 10 years). According to a recent study[12], Canada ranks second in the world in terms of potential for the deployment of AWE technologies: excellent technical resources, a large potential market, governmental investment in wind energy and a high intellectual property right protection are just a few reasons to make the prospects of the AWE deployment in Canada very promising. Nevertheless, Canada's share in the R&D of this thriving field with promising economical and minimal ecological impact is unfortunately negligible. In the United States, 11 companies and institutions have academic and commercial activities in AWE development; this number for Germany is 9. The New Leaf-Concordia-UVic initiative is essential for bridging the substantial gap between Canada and other industrialized nations in pursuing AWE technologies. Such initiatives cannot succeed without the support and investment by the Canadian government and its agencies.

References
1. Islam, M. R., Mekhilef, S., Saidur, R. (2013). Progress and recent trends of wind energy technology. *Renewable and Sustainable Energy Reviews* 21, 456-468.
2. The Canadian Wind Energy Association, Installed Capacity, Accessed on March 13, 2019, anwea.ca/wind-energy/installed-capacity.
3. Willis, D.J. et al, (2018). Wind energy research: State-of-the-art and future research directions. *Renewable Energy* 125, 133-154.
4. Wolf, A., Lutz, T., Würz, W., Krämer, Stalnov, O. (2015). Trailing edge noise reduction of wind turbine blades by active flow control, *Wind Energy* 18, 909-923.
5. Manson, G.K. (2005). On the coastal populations of Canada and the world, In Proceeding of the 12th Canadian Coastal Conference, Dartmouth, NS, Canada.
6. The Bahrain World Trade Center, Accessed on March 14, 2019, en.wikipedia.org/wiki/Bahrain_World_Trade_Center.
7. Dilimulati, A., Stathopoulos, T., Paraschivoiu, M. (2018). Wind turbine designs for urban applications: A case study of shrouded diffuser casing for turbines. *Journal of Wind Engineering & Industrial Aerodynamics* 175, 179-192.
8. KC, A., Whale, J., Urmee, T. (2019). Urban wind conditions and small wind turbines in the built environment: A review. *Renewable Energy* 131, 268-283.
9. Near Zero, Energy High in the Sky: Expert Perspectives on Airborne Wind Energy Systems, ed. Mason, I., 9 September 2012, Accessed on March 13, 2019, nearzero.org.
10. Kheiri, M., Bourgault, F., Saberi Nasrabad, V., Victor, S. (2018). On the aerodynamic performance of crosswind kite power systems. *Journal of Wind Engineering & Industrial Aerodynamics* 181, 1-13.
11. Kheiri, M., Saberi Nasrabad, V., Bourgault, F. (2019). A new perspective on the aerodynamic performance and power limit of crosswind kite systems. *Journal of Wind Engineering & Industrial Aerodynamics* [Accepted].
12. Wijnja, I.J. (2014). Global Opportunities for Airborne Wind. MSc Thesis, Delft University of Technology, Delft, Netherlands.

Energy Efficiency continued from page 12

play an important role to break through these mysteries. In the same way, optical methods like Particle Imagery Velocimetry or Infrared Thermography, which are now quite classical in the fluid mechanics or heat transfer community, could be used to provide more local information on the flow or thermal fields in components of refrigeration systems and validate CFD models.

This improved knowledge would enable to develop more accurate and relevant thermodynamic or 1D models by relaxing some very restrictive assumptions, which is the second key perspective. Associated with multiobjective algorithms, they may constitute very powerful aided-design tools, integrating performance but also economic, environmental and societal criteria. The Coefficient of Performance or the overall energy efficiency can not be the only criteria to compare two technologies. Exergy efficiency is a more interesting metrics to identify the source of losses. It should also include the payback period, metrics issued from Life Cycle Analysis or social acceptation criterion.

Finally, refrigeration should be certainly more inspired by nature. Biomimicry is not only a very fashionable topic for researchers. It offers answers to technological problems by time-tested patterns and strategies. Why not optimizing the heat transfer area in caloric regenerators or thermal energy storage systems by referring to honeycombs? Bio-inspired surfaces could also help reducing the pumping power required to transport cold by ice slurries. Nature already proposes a variety of optimal forms, which minimize the amount of materials and energy required for a given system. The Eastgate Center in Zimbabwe is the proof that biomimicry concepts could be applied successfully. Inspired by the air distribution in termitary, it consumes only 10% of the total energy required for the air-conditioning of similar buildings despite summer temperatures reaching up to 45ºC. Recycling the waste heat of an oil refinery to produce hot water for greenhouses is one of the few examples of industrial symbiosis, currently applied at a larger scale by some cities like Kalundborg in Denmark. Efforts should continue in that direction.

To sum up, refrigeration is a very alive research topic, which draws upon knowledge from a wide range of disciplines like engineering, of course, but also chemistry, physics and biomimicry and which will get even more a central preoccupation in the upcoming few years.

References
1. Lamberts, Olivier; Chatelain, Philippe; Bartosiewicz, Yann (2017). New methods for analyzing transport phenomena in supersonic ejectors. I*nternational Journal of Heat and Fluid Flow*, Volume 64, pages 23-40.

Flight Science: Mathematics • **Techniques • Sensibility**

by Layla S. Mayboudi

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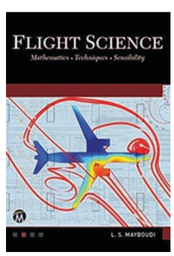
ISBN-13: 978-1683922155



This book introduces certain aspects of mathematics and sciences in general, as they relate to the subject of aviation, from the wheels-up to the wheels-down, and the time in between. The topics include meteorology, thermodynamics, combustion, drones, mechanics, dynamics, navigation, flight plans, critical distances, and general aviation-related guidance. The book also presents the use of statistical analysis in describing the aircraft characteristics based on performance charts. The book may be used as a reference and includes examples and case studies with step-by-step solutions. Readers new to the field who are working towards their recreational, private, or commercial licenses or one already flying a single piston or multi-engine aircraft will benefit from the content.

Heat Transfer Modelling Using COMSOL®: Slab to Radial Fin **(Multiphysics Modeling Series)**

by Layla S. Mayboudi

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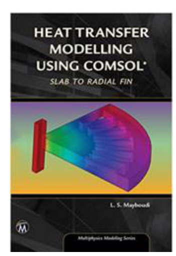

Fins have been used historically as reliable design features for thermal management, which continues to be an important problem in engineering today. This book develops heat transfer models for progressively complex fin designs. Mathematicians, engineers, and analysts may equally benefit from the content as it provides the reader with numerical and analytical tools to approach general and thermal management heat transfer problems. The main focus is on the COMSOL Multiphysics® Heat Transfer module; however, the fundamentals may be applied to other commercial packages such as ANSYS® and Abaqus™. The content can be utilized in a variety of engineering disciplines including mechanical, aerospace, biomedical, chemical, civil, and electrical.

Available to order from the publisher www.merclearning.com or Amazon.ca.

Montesano continued from page 19

evolution data for different FRP laminates subjected to uniaxial and multiaxial cyclic loads, the results of which have been published in the journals *Composites Part A*, *Polymer Testing* and C*omposites Part B*. The generated data has been beneficial for improving understanding of material durability and for informing prediction models.

From the computational side the group's research involves developing physically-based multi-scale models to predict failure in FRP materials and wind turbine blade structures (see *Figure 2*; Montesano J, McCleave B, Singh CV. *Composites Part B* (2018), Vol 133, pp 53-67). The modeling approach provides a means to perform virtual tests which is a useful tool for the design of FRP composite structures. At the microscopic length scale, computational models that accurately represent the two-phase microstructure of FRP materials are developed using novel techniques and used to predict local damage initiation events. Damage-based constitutive models, calibrated from the micro- and meso-scale models, are then developed to predict the influence of local damage states on the stiffness of FRP composite materials. Finally, through custom user-defined subroutines the constitutive models are integrated with commercial finite element software to assess the durability of full-scale wind turbine blades (see *Figure 2*). The results of this work have been published in various journals including *Renewable Energy, Materials & Design*, *Composite Structures*, *Composites Part B* and *Mechanics of Materials*.

In addition, Dr. Montesano's group has recently received funding through the Canada Foundation for Innovation (CFI) and Ontario Research Fund (ORF) and developed an Advanced Composites Processing Facility. The infrastructure has enabled additional research topics, including developing new processes for rapidly fabricating composite parts and studying the impact performance of FRP materials.

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optics. Dr. Cooper's research has pioneered the use of thin metallized polymer membranes, suitably inflated to form low-cost mirrors. Such inflated polymer mirrors are light-weight, transportable, deployable, and recyclable and can reduce the cost by more than a factor of 10 vis-à-vis traditional mirror constructions. In addition to boosting the temperature of solar thermal processes, concentrators can also boost the efficiency of photovoltaic cells and reduce the cell area required to produce a given amount of power. Details of this concentrating photovoltaic study are published in *Progress in Photovoltaics*, vol. 24, pp. 1410-1426. The CooperLab is currently working on low cost inflated collectors specifically optimized for operation in northerly climates, with the aim of making solar energy more accessible in countries like Canada.

To obtain even higher temperatures, concentrators are coupled with wavelength-selective receivers, which exhibit high absorptance in the solar spectrum, and low emittance in the thermal infrared spectrum. Traditional selective surfaces rely on ceramic-metal composites (cermets) which have a limited service temperature and often require being enclosed in a vacuum jacket to prevent oxidation. During his postdoc at MIT, Dr. Cooper worked on an alternative approach to achieve wavelength-selectivity using transparent, thermally insulating silica aerogel. By engineering the nanoscale morphology of the aerogel, monolithic aerogels with transmittance >95% (better than optical-grade glass) yet with a thermal conductivity <0.1 W/m^{2}K at 400°C (rivalling the best thermal insulators), were realized (see panel C of the figure). When placed above a blackbody absorber, these aerogels allow sunlight to pass through, while blocking heat losses by conduction, convection and thermal radiation, thus effectively trapping the heat in the absorber. Panel D of the figure shows the Solar Thermal Aerogel Receiver (STAR) prototype capable of delivering heat at temperatures up to 400°C. At these temperatures, the heat can effectively be used to displace fossil fuels as the energy input to traditional steam turbine power plants. Currently, the CooperLab is working on producing aerogels from other metal oxides with the goal of tuning the optical and thermal properties and increasing the maximum service temperature. So far, temperatures up to nearly 1000°C have been successfully demonstrated.

Beyond 1200°C, temperatures are high enough to thermally break chemical bonds and drive endothermic chemical reactions using solar energy. The most interesting of such reactions are water and CO_2 splitting, to produce H_2 and CO respectively. H_2 and CO can be subsequently transformed using gas-to-liquid technologies (e.g. Fischer-Tropsch synthesis) to produce liquid hydrocarbon fuels, effectively storing solar energy in chemical bonds. When the CO_2 is extracted from the air via direct-air capture technologies, the resulting process yields "solar fuels" from three ingredients alone: water, air, and solar energy. Importantly, this process is entirely carbon-neutral since for every amount of CO_2 emitted during the combustion of the fuel, an equivalent amount of CO_2 is sucked out of the air to start the synthesis process again. Solar fuels provide a paradigm-shift in how we think about hydrocarbon fuels: rather than thinking of fuels as something non-renewable dug up from the ground, we can think of them as a renewable way of storing solar energy in a convenient and dispatchable form that is compatible with existing transportation and industrial infrastructure. While at ETH Zurich, Dr. Cooper developed novel Al- and Ca-doped lanthanum manganite perovskite materials capable of catalyzing the water and CO_2-splitting reactions at lower temperatures, and with higher fuel yields than the state-of-the-art material ceria. The results of the research are published in *Energy Technology*, vol. 3, pp. 1130-1142. The CooperLab is currently developing nanostructured materials for CO_2 and H_2O splitting to boost the efficiency of the process.

In Canada, 21% of all primary energy use goes towards residential and commercial space and water heating. Moreover, a staggering 39% is used for industrial processes, many of which require this energy in the form of heat. An additional 29% of all primary energy use is for transportation, which relies on hydrocarbon fuels. Therefore, when we think about transforming to a sustainable energy future, we need to think beyond electricity. The solar thermal pathway provides a means for transforming sunlight into many useful forms spanning from clean water to renewable transportation fuels. By combining fundamental developments in materials, thermal science and optics with a system-level understanding of energy technology, Dr. Cooper's research strives to develop the technologies to transform the future of energy in Canada and contribute the mitigation of anthropogenic climate change.

EIC Awards
Call for Nominations

Established in 1887, the EIC is Canada's oldest engineering society and directly represented all engineering disciplines until the 1970's. It has since morphed into a federation of twelve learned engineering societies, including the CSME (est. 1970). The EIC now promotes strong continuing education standards, recognizes meritorious individual engineers through prestigious medals and fellowships, documents Canadian engineering history, holds thematic conferences and provides a policy advisory voice through the Partnership Group for Science and Engineering (PAGSE) and the Canadian Engineering Leadership Forum.

This year, two CSME Fellows were inducted as EIC Fellows at the EIC Gala held on 30 March in Ottawa/Gatineau: Professor Yuri Muzychka of Memorial University of Newfoundland and Professor Yang Shi of the University of Victoria. Congratulations to both!

Let's own the podium at the next EIC Awards Gala! Please consider nominating stellar mechanical engineers for the 2020 EIC Awards, details, including nomination form, are available at eic-ici.ca/honours_awards. The deadline for submission is November 15, 2019.

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