THE CANADIAN SOCIETY FOR MECHANICAL ENGINEERING
LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE
SPRING/PRINTEMPS 2025

BULLETIN

SPECIAL ISSUE ON

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SPRING/PRINTEMPS 2025

COVER IMAGE: MEDICAL TECHNOLOGY WITH AI SYSTEM ON DESKTOP COMPUTER SCREEN [SHUTTERSTOCK ID: 2578648913

Editor's Letter

WELCOME TO THE SPRING 2025 ISSUE of the Canadian Society for Mechanical Engineering (CSME) *Bulletin*. This issue aims at highlighting technologies developed by Canadian researchers that will help us live healthier and longer lives. The issue is co-edited with guest editors Prof. **Cuiying Jian**, representing Computational Mechanics (TC) and Prof. **Hossein Rouhani**, former TC chair of the Biomechanics and Biomedical Engineering. We hope that the issue will provide CSME members with an idea of what is happening in Canada in the area of biomechanics and bio-engineering.

This issue contains feature articles from research teams led by professors **Leping Li**, **Tian Tang**, **Lidan You** and **Alex Czekanski**. Dr. Li shows his work on knee joint finite-element-based contact mechanic simulation tools can improve osteoarthritis modelling, knee injury prevention and repair. Dr. Tang highlights her team's work on numerical design of elastomers and polymer gels, materials that can be used as scaffolds to support tissue regeneration, artificial organs, and for controlled delivery and release of drugs. Dr. You highlights the development of bone-on-a-chip (BoC) systems, which can be used for monitoring and better understanding bone health and bone diseases. Finally, Dr. Czekanski and his team shows us how artificial intelligence is helping the development of better computational models for soft materials.

Canada continues to train and recruit exceptionally talented researchers to our universities. This issue features spotlight articles introducing researchers working to help us live healthier and longer lives. This includes health-focused research by Dr. **Céderick Landry** (Sherbrooke University), who develops wearable cardiovascular health technologies, and by Dr. **Tais Sigaeva** (University of Calgary), who describes characterization and modeling of soft biological tissues. Furthermore, the work of Dr. **Elli Gkouti** (Western University) to develop smart materials by integrating AI with multi-physics simulations and Dr. **Keena Trowell** (McMaster University) to explore how aluminum can be used for "solid electricity" storage, helps us on our path to a safe and sustainable future.

To keep CSME members informed we also include information about the next CSME Congress (2026), CSME News, the CSME Student Affairs section, a list of future CSME awards and recent awardees, and a list of new CSME members.

Engineering and advanced education are always evolving. It is engineering progress on bioengineering that we are celebrating in this issue. However, similar advancements are occurring in generative artificial intelligence (AI). These advances have made it easier to quickly generate content, gather specialized information, and discuss points-of-view with a well-educated computer. The CSME *Bulletin's* aim is to share the detailed and in-depth perspective and advancements of Canadian researchers working in the field. To demonstrate our commitment, the Editorial Board has decided to implement the following AI policy: *"The CSME* Bulletin *will not accept any articles that have been generated by AI. To this end, all CSME* Bulletin *contributing authors will be asked to include a statement at the end of the article that notes that, even if AI was used for editing, the content is the original work of the authors. Furthermore, the authors will be asked to please provide an AI detector score, such as one generated from quillbot.com/ai-content-detector or www.scribbr.co.uk/ai-detector, and, if a percentage is AI-generated, justify the reason in the statement above."*

This policy aims at making sure that CSME *Bulletin* readers are guaranteed to read the firsthand experiences from CSME members, not the possibly false perspectives from generative-AI.

To conclude this letter, I would like to note that this is the last issue I will edit. I would like to take this opportunity to thank the CSME Editorial Board, all CSME *Bulletin* contributors and the CSME *Bulletin* readership. It has been a pleasure to serve as the CSME *Bulletin* editor. My goal during my tenure as editor has been to make sure the *Bulletin* serves as a good reference for all CSME members. To achieve this goal, we engaged CSME technical committee chairs to help us develop topical issues, expanded the number of feature articles and faculty spotlight articles, added a new members section to acknowledge the arrival of new members, and this issue, we implemented an AI policy. Starting next issue, Prof. **Ali Hosseini** from Ontario Tech University will serve as the CSME *Bulletin* editor. Prof. Hosseini has been an excellent technical editor for the CSME *Bulletin* and I believe he will continue to work diligently to ensure the CSME *Bulletin* remains a useful resource for CSME members. In addition, I would also like to welcome Prof. **Baafour Nyantekyi-Kwakye** from Dalhousie University and Prof. **Hassan Alkomy** from University of New Brunswick as the new Technical Editors for the CSME *Bulletin*.

Next issue will focus on advances in aerospace and will be co-edited with Profs. **Dana Grecov**, TC chair, Fluid Mechanics Engineering and **Yuping He**, TC chair, Transportation Systems. If you would like to suggest a topic for future issues, please let the CSME editors know your suggestions.

We hope you enjoy this issue of the CSME *Bulletin*.

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SUPPLIED PHOTOS

President's Message

Message du Président

PHOTO: ÉCOLE DE TECHNOLOGIE SUPÉRIEURE

Dear CSME members,

At a time of increasing global uncertainty and shifting international landscapes, the value and relevance of national societies such as the CSME have never been more evident. Canadian technical societies play an essential role not only in supporting their members but also in promoting open, inclusive, and collaborative academic and industrial communities at home and abroad. Within this context, the CSME continues to grow and serve as a vital hub for mechanical engineering in Canada.

This year, our committees have had a particularly productive term. The Task Force on Industrial Practices, led by Dr. **Mohammad Jahazi** (ÉTS), has strengthened CSME's engagement with industry through the launch of a new workshop series and the creation of the CSME Industrial Innovation Award, which will be presented to Mr. **Serge Lalonde** (Pratt & Whitney) at the 2025 Congress in Montreal—where the first workshop will also take place. The Equity, Diversity, and Inclusion (EDI) Committee, chaired by Dr. **Cuiying Jian** (York University), published a policy statement and hosted a well-received panel on "Why EDI in Engineering." The History Committee, under Dr. **Ian Frigaard** (UBC), began documenting the development of mechanical engineering departments across Canada. Meanwhile, the Student Affairs Committee, led by Dr. **Dan Romanyk** (University of Alberta), oversaw one of its most active years, launching new student chapters at Waterloo and UBC and supporting several successful industrial events nationwide.

Preparations are well underway for the 2025 CSME Congress in Montreal, co-hosted with the Canadian Society of CFD and the Canadian Society of Rheology. With over 600 submissions and more than 700 expected participants, this will be one of our largest and most dynamic congresses to date. The program will feature plenary, keynote, and technical presentations from world-leading experts, a strong industrial presence including spotlight talks and lunchtime pitches, and a plenary session hosted by the Engineering Institute of Canada focused on AI and sustainable engineering development. A variety of workshops and panels will further enrich the program. We thank Dr. **Lucas Hof** and his team for organizing what promises to be an outstanding event.

This year, we proudly recognize our award recipients: Dr. **Jerzy Maciej Floryan** (Clifford N. Downing Award), Dr. **Dominic Groulx** (Jules Stachiewicz Medal), Dr. **Cuiying Jian** (I.W. Smith Award), Dr. **Mohsen Akbari** (Emerging Technologies Medal), and Dr. **Ya-Jun Pan** (Mechatronics Medal). We also congratulate our new CSME Fellows: Dr. **Martin Agelin-Chaab**, Dr. **Hamid Akbarzadeh**, Dr. **Tobin Filleter**, and Dr. **John Wen**.

I would like to sincerely thank our Executive Director, **Guy Gosselin**, for his continued leadership and support. Under his direction, the membership system has been upgraded to improve access to receipts and member benefits, and we are preparing for a major update to the CSME website to better serve our community. I also thank Dr. **Marc Secanell Gallart** (University of Alberta) for his outstanding work as Editor of the CSME *Bulletin*, and welcome Dr. **Ali Hosseini** (Ontario Tech University) as he takes on this important role.

I look forward to seeing many of you in Montreal for the 2025 CSME Congress. Let's stay engaged and continue to strengthen our community together. The CSME thrives because of you, serves you, and truly is you.

Sincerely,

ALI AHMADI, PhD, P.Eng., MCSME
CSME *President, Associate Professor*
Department of Mechanical Engineering
École de Technologie Supérieure

Chers membres de la SCGM,

À une époque marquée par une incertitude mondiale croissante et un contexte international en constante évolution, la valeur et la pertinence des sociétés nationales comme la SCGM n'ont jamais été aussi évidentes. Les sociétés canadiennes jouent un rôle essentiel, non seulement en soutenant leurs membres, mais aussi en favorisant des communautés académiques et industrielles ouvertes, inclusives et collaboratives, tant au pays qu'à l'étranger. Dans ce contexte, la SCGM continue de croître et de servir comme carrefour incontournable du génie mécanique au Canada.

Cette année, nos comités ont connu un mandat particulièrement productif. Le Groupe de travail sur les pratiques industrielles, dirigé par le Dr Mohammad Jahazi (ÉTS), a renforcé l'engagement de la SCGM envers l'industrie grâce au lancement d'une nouvelle série d'ateliers et à la création du Prix d'innovation industrielle de la SCGM, qui sera remis à M. Serge Lalonde (Pratt & Whitney) lors du Congrès 2025 à Montréal—lieu où se tiendra également le tout premier atelier. Le comité sur l'équité, la diversité et l'inclusion (EDI), présidé par la Dre Cuiying Jian (Université York), a publié une déclaration de principe et animé un panel fort apprécié intitulé « Pourquoi l'EDI en génie ». Le comité d'histoire, sous la direction du Dr Ian Frigaard (UBC), a amorcé la documentation de l'évolution des départements de génie mécanique à travers le Canada. Parallèlement, le comité des affaires étudiantes, dirigé par le Dr Dan Romanyk (Université de l'Alberta), a connu l'une de ses années les plus actives, lançant de nouveaux chapitres étudiants à Waterloo et à l'UBC et soutenant plusieurs événements industriels réussis à l'échelle nationale.

Les préparatifs vont bon train pour le Congrès 2025 de la SCGM à Montréal, organisé en collaboration avec la Société canadienne de CFD et la Société canadienne de rhéologie. Avec plus de 600 soumissions et plus de 700 participant.es attendu.es, ce sera l'un de nos plus grands et plus dynamiques congrès à ce jour. Le programme comprendra des présentations plénières, des conférences principales et des communications techniques données par des experts de renommée mondiale, une forte présence industrielle incluant des mini-présentations et des séances sur l'heure du dîner, ainsi qu'une plénière animée par l'Institut canadien des ingénieurs sur l'intelligence artificielle et le développement durable en génie. Une variété d'ateliers et de panels viendront enrichir davantage le programme. Nous remercions le Dr Lucas Hof et son équipe pour l'organisation de ce qui promet d'être un événement exceptionnel.

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Canadian Science Publishing

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

WELCOMING NEW EDITORS-IN-CHIEF TO TCSME

Transactions of the Canadian Society for Mechanical Engineering (TCSME) welcomed Drs. **Jerzy Maciej Floryan** (Western University) and **Aleksander Czekanski** (York University) in June 2024! Thank you to our outgoing Editor-in-Chief Marius Paraschivoiu for his many years of dedicated service. Marius remains on the Board as a Consulting Editor.

LOOKING FORWARD TO CSME CONGRESS – SEE YOU IN MONTREAL!

TCSME is proud to be supporting the Best Student Paper Competition at CSME-CFDSC-CSR International Congress 2025 and will have a booth at the Exhibition Hall. We are endeavoring to de-mystify the publishing industry by providing a space for learning, conversation, questions and feedback at two events, **The path to publication: Processes and new horizons in academic publishing** and **Teaching, research, and publishing in the age of AI** *(panel participation).*

WAIVERS FOR ARTICLE PUBLICATION CSME PROFESSIONAL MEMBERS AND CANADIAN AUTHORS

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

- CSME members can publish in TCSME free of charge through a **partnership agreement which covers all page charges** – please identify your membership upon paper acceptance to qualify!
- Canadian Research Knowledge Network open access agreement enables corresponding authors from CRKN-affiliated universities (>40 universities) to **publish free and unlimited open access in TCSME**.

Read more about these agreements: cdnsciencepub.com/journal/tcsme/publication-fees

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For general inquiries, contact TCSME's Journal Development Specialist Jocelyn Sinclair at Jocelyn.Sinclair@cdnsciencepub.com.

Canadian National Committee for Mechanics

The Mission of this Committee is to represent Canada at the International Union for Theoretical and Applied Mechanics (IUTAM) and to popularize mechanics in Canada. It is chaired by Dr. JM Floryan from Western University (floryan@uwo.ca).

CNC promotes scholarly pursuits in mechanics and conference participation to support early-career research development by sponsoring three symposia during the 2025 CSME International Congress, i.e., Symposium on Fluid Mechanics, Solid Mechanics, and Computational Mechanics, and sponsoring prizes.

The Committee has established prizes for the best presentation during these symposia. The awards are designated for junior researchers, encompassing individuals up to the rank of assistant professor. Three awards may be presented: one for presentation during the Fluid Mechanics Symposium, another during the Solid Mechanics Symposium, and the third during the Computational Mechanics Symposium. The awards are granted following a comprehensive evaluation of the oral presentation's quality. This assessment encompasses the clarity and effectiveness of delivery, the use of visual aids, and the presenter's ability to respond to questions with precision.

CSME-CSR 2026

A joint conference of the CSME and Canadian Society of Rheology
May 24-27, 2026
University of British Columbia (UBC), Vancouver (BC)

The Canadian Society for Mechanical Engineering (CSME) and the Canadian Society of Rheology (CSR) will hold their joint 2026 CSME-CSR International Congress at the University of British Columbia (UBC) in Vancouver (BC) on May 24-27, 2026. This international congress presents a unique opportunity to exchange new knowledge in the many fields of mechanical engineering and to build strong networks between academia, research, and industry to help accelerate innovation.

Call for Abstracts & Papers

- Both abstracts (up to 400 words) and papers (up to 6 pages) are accepted and welcome
- Papers first-authored by students are eligible for the student paper competitions
- **Submission deadline: January 30th, 2026** (see www.csmecongress.org for updates)

Additional Information and Sponsorship

- Call for special symposia and workshops
- Sponsor? – Please contact csme2026@ubc.ca
- For any questions, inquiries, and/or proposals, please contact csme2026@ubc.ca

CSME Symposia	Advanced Energy Systems	Materials Technology
	Advanced Manufacturing	Mechatronics, Robotics & Controls
	Biomechanics & Biomedical Engineering	Microtechnology & Nanotechnology
	Computational Mechanics	Smart Production Systems
	Engineering Analysis & Design	Solid Mechanics
	Environmental Engineering	Sustainable Practices in Engineering
	Fluid Mechanics	Thermal Science & Engineering
	Machines & Mechanisms	Transportation Systems
CSR Symposia	Theoretical & Computational Rheology, Rheometry	Applied Rheology

* For further information, visit www.csmecongress.org.

POPULATION DIVERSITY IN KNEE JOINT CONTACT MECHANICS AND RELATED CLINICAL IMPLICATIONS

FINITE ELEMENT MODELLING MAY BE THE most convenient way to determine fluid pressurization in cartilage and meniscus and related creep and relaxation behaviours of the knee joint. Our ongoing research is to determine the effect of sex and race in knee joint mechanics, which may have implications in clinical outcomes, e.g., different tissue repair strategies may be required for different individuals to improve the success rate of joint surgeries. We have recently established a framework that combines statistical shape modelling in finite element simulations to address differences among individuals in a subpopulation. We will apply the framework to different subpopulations to understand the intra- and inter-variations in knee joint mechanics.

Knee joint contact mechanics and finite element modelling

Our knees perform various mechanical functions during daily activities and, hence, normal joint mechanics is essential to joint health. A knee joint failure is ultimately a mechanical failure, even though it often involves disease progression in one or more joint tissues, such as articular cartilage, menisci and/or ligaments. For example, abnormal joint mechanics may cause knee cartilage degeneration, and vice versa.[1,2] The complexity of the knee joint is mostly due to multiple mechanical contacts of several tissues with irregular shapes, e.g., crescent-shaped menisci are sandwiched between femoral and tibial cartilage. Finite element modelling has been widely used to predict the biomechanical behaviour of the knee joint at the cell, tissue and joint levels in order to understand common tissue injuries and development of osteoarthritis.[3,4] Specifically, it has been used to elucidate compromised joint mechanics due to ligament injuries[4] and meniscectomy.[5,6] The latter is a surgical procedure to remove a completely or partially torn meniscus, referred to as total or partial meniscectomy, respectively.

Fluid pressurization and flow within cartilage and menisci facilitates joint load support and tissue homeostasis. Mechanically, it offers a variable effective tissue stiffness with the pressure change, which modulates load distribution and lubrication in the joint. Interestingly, interstitial fluid pressurization dominates the relaxation and creep responses in articular cartilage when subjected to compressive loading.[7] Biologically, cartilage relies on fluid flow to bring nutrients to its cells and take waste away.[1] Therefore, it is important to determine fluid pressurization in knee cartilage to understand its injury and degeneration. However, most published studies overlook the fluid phase in whole-joint models, although multiphasic constitutive models have been extensively proposed from explant experiments. My team has attempted to bridge the gap between in-vitro and in-vivo cartilage mechanics using porcine and human knee joint models to understand the fluid-pressure dependent mechanical response. Lab tests with porcine knees revealed creep response in situ and site-specific tissue properties of knee cartilage. Substantial creep responses were observed in human knees in-vivo within minutes of standing. Finite element modelling has been used to determine contact and fluid pressures in the joint[8] nearly impossible to measure experimentally.

Subject-specific finite element models are usually reconstructed from MRI/CT. It is key to implement valid constitutive laws in a joint model to obtain meaningful numerical results. Since the collagen fiber network plays a vital role in fluid pressurization[9], we use fibril-reinforced models for the cartilaginous tissue, in which cartilage or menisci are considered as a fluid-saturated porous reinforced by an elastic or viscoelastic fibrillar matrix.[10,11] The interplay between nonlinear fibril reinforcement and fluid pressurization determines the mechanical response to compressive loading.[11] Consequently, fibril-reinforced fluid pressurization will likely become an essential feature in all cartilage modelling as it has received increased attention over recent years.[12] In constitutive modelling, or model studies at the tissue level, fibril reinforcement has been formulated and applied for articular cartilage at different mathematical complexities by different research groups worldwide.[13] Our tissue model approximates this mechanism with simplicity to facilitate clinical implementation.[10,11]

Statistical shape modelling to characterize variations in a subpopulation

Subject-specific knee joint modeling has been developed and evolved since the 1990s, offering valuable insight in joint repair and disease progression.[3,5,6] However, there are limited modeling studies exploring the impact of individual knee geometry on knee joint contact mechanics. Instead, published results are primarily based on finite element simulations of one or a

LEPING LI, PhD

Dr. Li is a professor with the Department of Mechanical and Manufacturing Engineering at the University of Calgary, with a focus on solid mechanics and biomechanics. He was trained in multicultural and multilinguistic environments with a PhD at Ben-Gurion University in Israel, and a postdoc at Polytechnique Montréal in Canada. He and his collaborators are among the first to introduce fibril reinforcement in articular cartilage models to explain the nonlinear creep and relaxation responses observed from mechanical testing. His team has implemented their developed tissue models in subject-specific knee models validated against human subjects and porcine joints. His current research focus pertains to in-vivo fluid pressurization in cartilage and menisci of the knee joint in large-scale population studies.

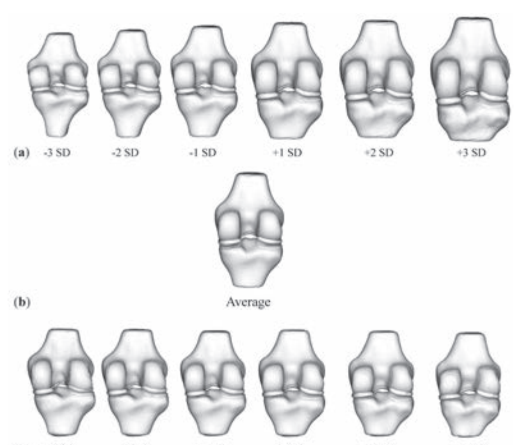

FIG. 1. SYNTHETIC KNEE MODELS GENERATED FROM STATISTICAL SHAPE MODELING: (A) MODE VARIATION CHARACTERIZED BY PRINCIPAL COMPONENT 1; (B) AVERAGE KNEE FROM 31 CAUCASIAN MALES (NORMAL RIGHT KNEES, OR ZERO KELLGREN-LAWRENCE SCORE); AND (C) MODE VARIATION BY PRINCIPAL COMPONENT 2. THE SYNTHETIC MODELS WERE PRODUCED FROM SUBJECT-SPECIFIC MODELS RECONSTRUCTED FROM MRI: SYNTHETIC KNEE = AVERAGE KNEE ± N SD, SHOWN FOR N = 0-3. SD, THE STANDARD DEVIATION, IS DIFFERENT FOR DIFFERENT PRINCIPAL COMPONENT.

couple of individual knees, and hence, may not be applicable to other individuals. For example, when comparing a meniscectomy in the lateral to medial compartment of the knee, one study revealed more compromised joint mechanics with medial meniscectomy[5], while another study indicated a more detrimental effect of lateral meniscectomy.[6] Among many factors that may contribute to different results, a noteworthy one may be the diversity in knee geometry within a population or overall differences in sex and race.[14]

Statistical shape modeling, which has been widely used to capture shape variations in a single tissue for a population, has recently been extended to characterize diverse 3D geometric variability at the whole joint level.[15] The variations in knee morphology are approximated by several principal components that are ranked in order of significance, i.e., the first principal component describes the largest variance in the dataset. A small number of principal components would normally explain most variations in the dataset for a specific population. For example, in a study involving six female and eight male participants, the initial six principal components captured 70% of the variance exhibited in their right knees.[15] Synthetic knee models are used in analysis (*Fig. 1*), which are mathematically produced by perturbing the average knee along a principal component direction for several standard deviations (note that the average knee is also synthetic, or computationally generated from the subject-specific models of the entire subpopulation). Consequently, a specific mode variation in knee morphology is highlighted in synthetic models and the related changes in mechanics may be effectively identified.

We have developed a framework of shape modelling in finite element simulations to address the intra-variation in knee joint contact mechanics within a subpopulation.[16, 17] To test the methodology, MR knee images from a small dataset of 31 Caucasian males (55±7.6 years) were acquired from the Osteoarthritis Initiative (nda.nih.gov/oai). In this cohort, the initial seven principal components accounted for 80% of the total observed variability in knee joint geometry, with principal components 1 and 2 (PC1 & PC2) representing, respectively, 44.5% and 14.5% of the knee geometric variations in the subpopulation. PC1 mainly captured differences in overall size of tibial-femoral joints with minor variances in joint shape. For example, the distal femur of the +3SD model of PC1 was approximately 12% larger in its maximum dimension in the lateral-medial direction, as compared to the average model (*Fig. 1*). On the other hand, PC2 predominantly reflected changes in the curvature of the tibia and femur (*Table 1*), which may be less obvious than size changes (*Fig. 1c*).

Finite element modelling of a synthetic knee (*Fig. 1*) follows the same procedure as that of subject-specific joint modelling after the synthetic surfaces of all tissues have been generated. In addition to stresses and strains, contact and fluid pressures in PC1 and PC2 knee models were determined during knee compression and creep. As expected, the magnitude of contact pressure was found to be predominantly affected by the joint size variation in PC1 mode variation because a larger joint normally has a larger contact area, resulting in a lower contact pressure under given loading (*Table 2:* for a given compression, ~20% decrease in the maximum contact pressure for larger +3SD models, and ~50% increase for smaller —3SD models). The other results in *Table 2* may appear to be unexpected without finite element analysis, as two interesting findings are demonstrated in this table. First, the variation in the maximum fluid pressure does not follow that of maximum contact pressure: for PC1 models, the fluid pressure barely decreases with the larger +3SD model; for PC2 models, the +3SD model experiences a greater contact pressure increase, while the —3SD model experiences greater fluid pressure increase. Second, any shape deviation from the average knee pertaining to PC2 would produce substantial increase in both contact and fluid pressures. The first finding indicates the importance of fluid pressure modelling. Specifically, fluid pressure inside the tissue, which may play an important role in tissue injury and degeneration, cannot be derived from contact pressure on articular surfaces. The second finding may indicate minimized stress concentrations in the average knee as compared to that with PC2 mode variation, indicating these knees may be more prone to tissue injury and degeneration.

Implication and challenges of population modelling in clinical studies and treatment outcomes

Our results showed that PC2 knee shape variation substantially affected cartilage maximum contact and fluid pressures while the overall knee sizes of the ± 3SD models were approximately the same as that of the average model (*Table 2*). Since PC1 only represented 44.5% knee geometric variations in the cohort, this may indicate that 55.5% of the subpopulation represented by the rest of principal components would be overlooked if only size effects are investigated in finite element simulations. Furthermore, the fact that the fluid pressures did not follow the contact pressure patterns in both PC1 and PC2 models implies that cartilage degeneration may not start from the contact centre or high load bearing areas. Rather, it may also be influenced by knee-geometry-dependent fluid pressurization and flow in the tissue. These findings may support observed different clinical outcomes of meniscectomy for different patients. On the other hand, these results underscore the need of fluid pressure modelling over commonly used elastic modelling that ignores the fluid phase in cartilage and menisci in whole joint models.

Statistical shape modelling may be a promising approach for the determination of joint contact mechanics of a large population since a few principal components may characterize

. . . continued on page 30

Table 1: Anatomical parameters characterized by the average knee, and principal component 2 variation (= Average ± 3 SD). SD stands for standard deviation.

		Average knee	-3 SD	+3 SD
Maximum surface curvature at bottom of femoral condyles (mm^{-1})				
Frontal plane	Lateral condyle	1.00	0.83	1.83
	Medial condyle	0.40	0.72	0.21
Sagittal plane	Lateral condyle	0.73	2.58	0.76
	Medial condyle	2.65	3.01	0.97
Shift of centroid with reference to the average model (mm)				
	Lateral tibial cartilage	Reference	-1.72	1.73
	Medial tibial cartilage	Reference	-1.61	1.62

Table 2: Maximum contact and fluid pressure increase/decrease from that of the average knee, shown for (Average ± 3 SD) knees under three conditions: *none*, *partial* and *total* medial meniscectomies. Calculated for tibial cartilage for the time immediately after 400-N compression was applied in 1s; for fluid pressure at 3/8 tissue depth [17]. Note that the reference is the average knee, respectively, under the three conditions.

Meniscectomy		Principal component 1		Principal component 2	
		+3 SD	**−3 SD**	**+3 SD**	**−3 SD**
Contact pressure	*None*	−21%	+50%	+66%	+27%
	Partial	−21%	+51%	+67%	+28%
	Total	−23%	+46%	+61%	+25%
Fluid pressure	*None*	−2.5%	+66%	+97%	+153%
	Partial	−3.5%	+65%	+95%	+150%
	Total	−6.4%	+59%	+85%	+147%

HARNESSING THE POTENTIAL OF ELASTOMERS AND POLYMER GELS FOR BETTER QUALITY OF LIFE

TIAN TANG, PhD, P.Eng.

Dr. Tang is a professor in Mechanical Engineering at the University of Alberta, an elected Fellow of the Canadian Academy of Engineering and holds a Tier 1 Canada Research Chair in multiscale modeling of soft materials and interfaces. She has published over 150 articles in reputable international journals, and is the recipient of many awards, including the Adhesion Society's Outstanding Young Adhesion Scientist Award, the Martha Cook Piper Research Prize, Killam Annual Professorship and the University Cup.

HASHEM MOOSAVIAN, PhD

Dr. Moosavian is a postdoctoral fellow in Mechanical Engineering at the University of Alberta, where he completed his PhD in 2024 under the supervision of Dr. Tang. He is the recipient of several awards, including the Alberta Innovates Graduate Student Scholarship, in recognition of his academic excellence. His expertise is in the mathematical modeling of advanced materials, particularly polymers, focusing on bridging continuum mechanics and molecular scale.

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Elastomers and polymer gels

RENOWNED FOR THEIR ABILITY TO DEFORM under even small forces, polymeric soft materials like elastomers and gels are fundamental to a wide range of applications. Elastomers, known traditionally as rubber-like materials, can be substantially deformed while preserving their shape after unloading, distinguishing them from hard solids such as metals, ceramics, or glasses. For centuries, natural rubber, the first-ever known elastomer, has been used by Indigenous peoples who collected sap from the *Hevea* tree to make various goods, including sports balls, waterproof containers, fabrics, and shoes. However, synthesis of elastomers only began around 1839, when Charles Goodyear realized that heating raw rubber with sulfur produced a highly elastic material known as vulcanized rubber. In spite of progress in polymer technology in the 19th century, physics underlying the anomalous behavior of polymers remained a mystery until 1920. In this year, Staudinger introduced the concept of a macromolecule, which revolutionized the polymer industry. Following this groundbreaking idea, the field of polymer science was created, giving rise to the synthesis of a broad range of elastomers. Nowadays, elastomers are widely employed, examples ranging from automotive parts (tires, conveyer belts, hoses etc.) to personal healthcare items (smart watch bands, fitness trackers, wearable heaters etc.).

Polymer gels share the same polymeric component as elastomers but contain a significant amount of trapped liquid. Equipped with biocompatibility, non-toxicity, and the ability to transport liquid, many polymer gels are suitable for food industry and biomedical applications. For example, they can be fabricated as scaffolds to support tissue regeneration, or as artificial organs to reduce the dependence on organ donors.[1] In pharmaceutics, hydrogels can serve as a platform for controlled delivery and release of drugs, including in cancer therapy. Gels can also perform the role of substrates for stretchable electronics, e.g. deformable light-emitting displays or cameras with potential impact on biological imaging devices such as artificial retinal implants.[2]

Building blocks

The fundamental building blocks of elastomers are macromolecules, molecules that have many repeating units and weigh 1,000 to 1,000,000 times more than small molecules like water. The macromolecules are interconnected by junction points to form a three-dimensional network. In polymer gels, solvent molecules (e.g. water in hydrogels) are present in addition to the network. Each macromolecule interacts with itself, other macromolecules, and solvent molecules. These interactions highly depend on synthesis and can be divided into chemical and physical bonds.

Chemical bonds are covalent in nature and prevalent within the macromolecules. They are also present in chemical crosslinkers, tying different macromolecules together to produce specific architectures. Physical bonds arise from weaker forces such as hydrogen bonding, ionic bridging and van der Waals interaction. Some of these bonds impose constraints that prevent macromolecules from passing through each other, leading to entanglements. Others contribute to transient associations between macromolecules that break at one location and reform at another.[3]

Elastomers and polymer gels under loading

When subjected to zero force, macromolecules tend to assume a coiled configuration, to not only relax the bonds, but also maximize the entropy of the chains. Under mechanical loading, macromolecules transform from their coiled state to a more straightened state. Such extension can be many times the original size, which contributes to the large elastic deformation observed in elastomers. While the coiled state can be fully recovered after the removal of a modest load, above certain threshold bond breakage occurs in the macromolecules and/or at the junction points, resulting in a new, degraded, network. These molecular mechanisms are manifested at larger scale, in the form of defect nucleation, crack propagation, etc. Depending on the nature of broken bonds, such transformation may be irreversible or reversible. Notably, the reversible breakage and reformation of physical bonds in some materials have led to the fascinating phenomenon of self-healing.

Smart synthesis

The intriguing connection between molecular mechanisms and observable properties has inspired efforts to develop synthesis methods that capitalize on micromechanics to achieve desired material functionalities. Of particular mention is the seminal work by Gong et al.[4], which created the first double-network hydrogel. Aimed at overcoming the brittleness of traditional hydrogels, their strategy introduced two interpenetrating networks: one containing shorter, pre-stretched chains that sacrificially break to dissipate energy; and the other containing longer chains that maintain the material's integrity at large extensions. Based on this revolutionary idea, various methods have emerged to produce mechanically robust gels, examples

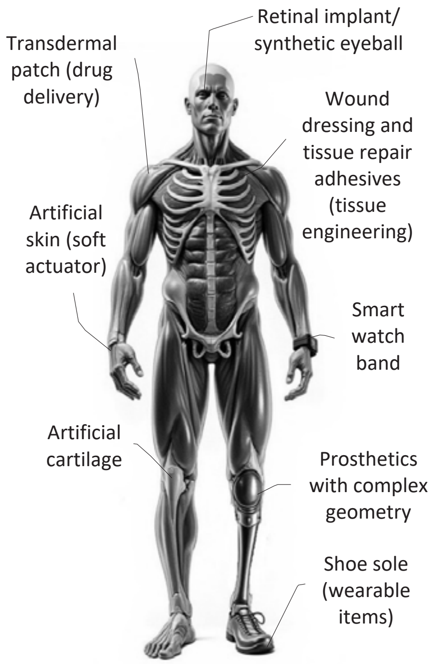


FIG. 1: EXAMPLES OF CURRENT AND ENVISIONED FUTURE APPLICATIONS USING ELASTOMERS AND POLYMERIC GELS. IMAGE OF HUMAN ANATOMY CREATED WITH THE ASSISTANCE OF GETIMG.AI.

including the introduction of both physical and chemical junctions, and purposely instigated entanglements. In parallel, approaches have been developed to create smart elastomers and gels that detect damage and release healing agents through mechanochemistry, or use designed junction points to control network architecture and enhance load sharing among macromolecules. Enhanced mechanical properties are crucial to biomedical application of elastomer and gels, ensuring their reliability and durability when serving, for example, as load-bearing synthetic tissues (e.g. cartilage, ligaments) or soft actuators (e.g. artificial skin).[1] *Figure 1* illustrates a few of the numerous applications where products made of smartly-synthesized elastomers or polymer gels can benefit our daily lives through healthcare, disease prevention, monitoring and treatment.

Scale-bridging modeling

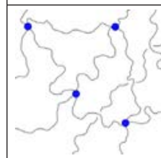
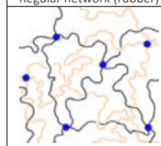
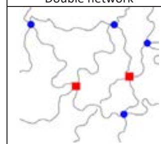
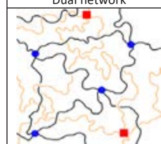
To harness the versatility in their synthesis and enable their full potential, trial-and-error experimentation can be complemented by scale-bridging modeling that aims at deciphering the materials' structure-function relationships, a key focus of our research group. *Table 1* lists a few examples of network structures in elastomer and gels, their properties and biomedical applications, as well as mathematical models describing their mechanical responses (including some of our own).[5-7] Despite great variation in details, these models share several common elements. The first is account of relationship between force and deformation at the single-molecule level, taking into consideration factors such as polymer chain architectures (e.g., linear, branched, or ring-like), interactions between segments, and potential bond scission and re-association.[5, 6] The second is *a priori* simplification of an irregular network into an ordered one composed of unit cells.[3, 8] The third is integration of individual macromolecules into the ordered network, establishing a connection between the load or displacement applied on the network and those felt by individual chains. In some models, the second and third elements are replaced by assumed affinity between the molecular and bulk deformations. Well-built scale-bridging models often contain synthesis parameters (e.g., molecular bond length and energy, monomer and crosslinker concentrations).[7] As such, they allow for a systematic and in-depth understanding of how the mechanics of the materials may be modulated via these parameters. Scale-bridging models have proven to be powerful tools in advancing polymer synthesis. For example, the imaginative "slip-link" model—considering pulley-like structures that glide along macromolecules[3]—proposed to describe entanglement later became a reality, leading to the development of slide-ring gels where mobile crosslinkers respond to external mechanical loading by reorganizing themselves, enabling applications that require high stretchability and recoverability.

The development of scale-bridging models has remained considerably behind the progress in synthesis, due to the intrinsic complexity associated with linking the mechanisms at different scales, as well as the trade-off between accuracy and applicability. Thanks to growing computing capabilities and infrastructure, numerical analysis of materials across different scales is becoming more affordable. Meanwhile, artificial intelligence (AI) is quickly advancing into polymer science and engineering. Notably, AI played a pivotal role in solving a 50-year-old problem on structure prediction of proteins, a breakthrough that contributed to the 2025 Nobel Prize in Chemistry. Building upon the vast amounts of existing experimental and theoretical data, AI can potentially determine the correlations between synthesis, microstructure, and observable properties while identifying the most influential parameters.[9] It can complement traditional mechanics modeling in inverse design of elastomers or gels, and optimization of their synthesis process.

Conclusion

Elastomers and polymer gels offer tremendous opportunities in many fields, especially in biomedical applications that impact people's healthcare and quality of life. Robust mechanical properties of these materials are essential to their functionality, which can be achieved through smart synthesis accompanied by scale-bridging modeling. AI is expected to play an increasingly important role in future designs of elastomers and polymer gels.

Table 1. Examples of synthesized elastomers and polymer gels (solvent not shown). Blue solid circles: chemical bonds, red solid squares: physical bonds.

Type of network	Examples (E), Properties (P), Applications (A), Mathematical Models (M)
 Regular network (rubber)	**E:** Vulcanized natural rubber (polyisoprene), polyurethane, silicone caulks (polydimethylsiloxane) **P:** Large deformability **A:** Cardiovascular devices, orthodontics, surgical implants, skin dressing, breast prostheses, medical devices **M:** Eight-chain network model, micro-sphere model, damage model, tube model
 Double network	**E:** PAMPS (poly(2-acrylamido-2-methylpropane sulfonic acid))/PAAM (polyacrylamide) gel **P:** Resistance against fracture **A:** Drug delivery, soft actuator **M:** Damage models
 Dual network	**E:** Dual cross-link poly(vinyl alcohol) gel **P:** Self-healing **A:** Tissue replacement, drug and biomolecule carrier **M:** Dynamic bonds model
 Hybrid network	**E:** Alginate–polyacrylamide hybrid gel **P:** Resistance against large deformation, energy absorbing **A:** Orthopedic applications e.g. prosthetics **M:** Viscoelastic double network model

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ENGINEERING SOLUTIONS FOR BONE HEALTH

BONE HEALTH REMAINS ONE OF THE MAJOR health challenges globally, with osteoporosis and bone cancer metastasis being leading factors devastating large populations worldwide. In Canada, more than 2 million people suffer from osteoporosis, with fractures costing $4.3 billion annually[1], and bone cancer metastasis occur in around 70% of advanced breast and prostate cancer patients.[2] Recent advances in bone-on-a-chip (BoC) systems provide a novel approach for understanding bone health and bone diseases. These platforms mimic the actual bone microenvironment by combining microfluidics, biosensing, and biomaterials. This allows for a more efficient treatment strategy to be developed in treating bone disorders. This article aims to review recent advancements in BoC technology and its role in advancing bone health study and bone disease treatment.

Bone Structure and Bone Cells

The material and mechanical properties of bones are regulated by a process called bone remodeling, making bone a dynamic structure. Mechanical loading is one of the many factors that regulate bone remodeling.[3] Osteocytes (mechanosensory cells), osteoblasts (bone-forming cells), and osteoclasts (bone-resorbing cells) are the three primary cell types that play a major role in bone remodeling.[4] Osteocytes are the most abundant bone cells in the bone matrix. They connect to each other to form a complex cellular network, and the space around them creates a pericellular space network known as the lacunar-canalicular system.[5] The pressure gradient generated by mechanical loading on the bone subsequently drives interstitial fluid flow in the lacunar-canalicular system and activates the osteocytes. Once stimulated, osteocyte respond with cellular signals regulating osteoblasts and osteoclasts activity. Bone integrity is determined by this dynamic interplay among these three main bone cells. Unfortunately, the unique bone structure, the dynamic mechanical microenvironment, and the critical inter-cell population cross talk are missing in conventional model systems, motivating better BoC designs to reflect these key features.

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Dr. You is a Tier 1 Canadian Research Chair in Cell Mechanics and Mechanobiology, and a Professor of Mechanical and Materials Engineering at Queen's University. Her research focuses on solving biomechanical questions in the musculoskeletal system. Her team recently developed advanced microfluidic systems for bone cell mechanotransduction and cancer bone metastasis studies.

Bone Health and Diseases: Osteoporosis and Cancer Metastasis

Bone integrity depends on the balance between the bone formation and bone resorption. Disruption of this balance leads to bone disorders such as osteoporosis.[6] Osteoporosis is a bone disorder causing reduced bone density and compromised bone microstructure, with postmenopausal women being particularly at high risk due to decreased estrogen levels. Cancer cells metastasized to bone also cause compromised bone structure. Pending on the side of the bone remodeling balance being disrupted, the resulting bone lesion can be osteolytic because of cancer cell triggered enhanced osteoclast activity or osteoblastic as a result of cancer-cell mediated increase in osteoblast activity.[7] Given the critical role of cross talk between cancer cells and bone cells, developing a BoC integrating the key cell populations involved is needed for better understanding cancer bone metastasis.

Limitations of Current Models for Studying Bone Diseases

Advances in understanding bone health and bone disease treatment have been achieved in past decades using in vitro and in vivo models. However, major limitations of these traditional models greatly hinder our capability in understanding bone physiological and pathological processes. Specifically, conventional in vitro models often fail to mimic the complex mechanical and biochemical microenvironment, such as loading induced cell signaling gradient and fluid flow in pericellular space surrounding bone cells, which are critical for bone cells to function appropriately.[3,8] Additionally, the inter cell populations cross talk, which is the key element in modelling various bone diseases, such as bone metastasis, is missing in most conventional in vitro model systems. In vivo models, while having all the necessary microenvironment key components for bone cell study, often have concurrent multiple factors that are hard to be isolated and evaluated in a controlled manner. Furthermore, in vivo animal model often differs from human bone in many aspects, such as remodeling rates and hormonal responses, leading to challenges in its translational potential.[9]

The Emergence of Bone-on-a-Chip and Organoid Technologies

Organ-on-a-chip (OoC) platforms offer unique opportunities to address these limitations by mimicking in vivo microenvironment and enabling interactions of multiple key cell populations in miniature devices. Bone-on-a-chip (BoC), as a subset of OoC, models specifically bone microenvironment, allows the study of specific physiological or pathological processes with multiple cell populations in a well controlled manner. Typically, such a system integrates microfluidic techniques and combines bone cells (e.g. osteocytes, osteoblasts, and osteoclasts) with other specific disease relevant cells, such as breast cancer cells for breast cancer bone metastasis. These platforms enable our investigation of bone health and bone disease mechanisms in a more physiologically relevant environment and hence, significantly improve the translational potential of the results obtained from these studies.

Recent Advancements in Bone-on-a-Chip Technology

1. Integration of Cell-Types Specific Mechanical Loadings

Dynamic mechanical loading is a critical regulatory factor for bone structure and function[2]. Conventional in vitro models often have the bone cells growing in a static environment, where the cell function could differ significantly from their normal status. Furthermore, most conventional in vitro models for bone study have only one type of cells grown in the system, leaving the critical real time cell-cell communications among all relevant cell populations missing. This greatly limits our ability in investigating bone cell functions. To address this concern, our group had recently engineered BoC systems which integrate multiple bone cell types, cell type specific mechanical stimuli applications and real time inter-cell population interactions enabled on chip.[10–12]

Our BoC systems provide a unique platform for investigating how mechanical loading regulates the bone remodeling process in a well controlled manner, allowing us to study the specific role of each involved bone cell type in its spe cific mechanical and biochemical environment. Moreover, by integration of other cell types, such as endothelial cells and cancer cells, our platforms, for the first time, enable the investigation of bone disorders, such as bone metastasis development in a more physiologically relevant environment (*Fig. 1*).[10,13,14] These capabilities greatly advance our understanding of bone disease mechanisms.

2. Integration of Biosensors for Real-Time Monitoring

One major advance in BoC model development is the integration of biosensors on chip for real time, continuous monitoring the level of key biomarkers such as oxygen, glucose, and lactate.[15] For example, Misun et al. (2016) developed a BoC platform with electrochemical sensors incorporated. This platform has the capability of real time glucose consumption and lactate secretion monitoring, significantly increasing the temporal resolution of biomarker analysis in bone cell metabolism research.[16] Such systems greatly advance our capabilities for investigating dynamic bone remodeling processes, drug responses, and disease progression.[17]

3. AI-Driven High-Throughput Platforms

Recent advancement in artificial intelligence (AI) has further improved the BoC model systems' scalability and precision. Paek et al. (2022) developed a high-throughput BoC platform with integrated osteoblast-derived decellularized extracellular matrix and AI-assisted imaging analysis enabled for osteoporosis drug screening. This platform mimics an osteon, the base unit of cortical bone, and used AI algorithms to analyze nuclear translocation of a key biomarker, β-catenin, in osteoblasts, as the outcome variable in evaluating the therapeutic effects, offering significantly improved drug screening efficiency.[18]

4. Vascularized and Innervated Models

Integrating functional vasculature and neural networks represent another major advancement in BoC systems. Bone marrow contains multiple cell types and complex heterogeneous microenvironments with various niches critical for proper bone marrow function. Many the key niches, such as endosteal niches, are perfused with a vascular network. A recent study by Glaser et al. (2022)[19], for the first time, developed a bone-marrow-on-chip platform, where the endothelial and hematopoietic stems cells are integrated for form a vascularized bone marrow structure, offering a great platform to study hematopoiesis and drug effects in bone marrow.

5. Modular and Multi-Organ Systems

To study the systemic interactions between bone and other organ systems (e.g., cartilage, liver), Multi-Organ-on-Chip systems are needed. For instance, to study the interface between bone and cartilage in joints, joint-on-a-chip is developed to model the interaction of osteocytes, chondrocytes (cartilage cells), and synovial cells.[20] Such a system provides a powerful tool for investigating diseases involving bone interactions with other organs, such as bone-cartilage cross talk in rheumatoid arthritis and cardiovascular-bone interactions in osteoporosis.[21]

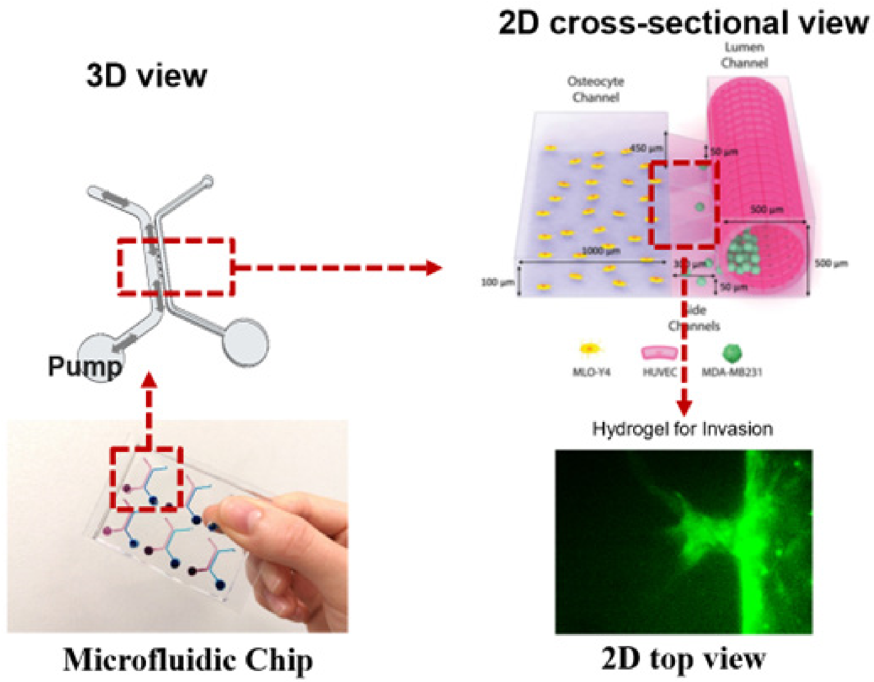

FIG. 1: BONE-METASTASIS-ON-A-CHIP. LOWER LEFT: MICROFLUIDIC CHIP WITH SIX MICROFLUIDIC DEVICES ARRAY. OSTEOCYTE CHANNEL IS DYED PURPLE AND THE LUMEN CHANNEL IS DYED BLUE; UPPER LEFT: 3D VIEW OF ONE MICROFLUIDIC DEVICE; UPPER RIGHT: 3D REPRESENTATION OF MICROFLUIDIC DEVICE WITH OSTEOCYTES SEEDED WITHIN THE OSTEOCYTE CHANNEL, BREAST CANCER CELLS SEEDED WITHIN AN ENDOTHELIAL LUMEN IN THE LUMEN CHANNEL, AND SIDE CHANNELS THAT THE BREAST CANCER CELLS INVADE INTO; LOWER RIGHT: 2D TOP VIEW OF FLUORESCENT IMAGES OF BREAST CANCER CELLS (GREEN) ESCAPING FROM THE ENDOTHELIAL CELLS LUMEN AND MIGRATING INTO THE SIDE CHANNELS.

6. Patient-Specific and Disease-Specific Models

BoC also offers unique opportunities for developing personalized treatment. Indeed, a 2023 BoC study using patient derived periodontal ligament cells to investigate the patient specific bacterial induced bone resorption, led to the identification of novel therapeutic targets, such as MMP-8 inhibitors.[22] Similarly, by incorporating patient derived leukemia cells, a recently developed hematological cancer BoC model demonstrated the effectiveness of the platform in investigating the drug resistance in myeloma and lymphoma diseases.[23]

Challenges and Future Directions

1. Standardization and Scalability: Variability in cell sources and fabrication methods hampers reproducibility. Modular designs and automated manufacturing, as proposed in recent reviews, could address this.[24]

2. Multi-Omics Integration: Combining genomics, proteomics, and metabolomics with BoC data remains technically challenging. Emerging microfluidic single-cell sequencing tools show promise.[15,23]

3. Clinical Translation: Regulatory frameworks for BoC platforms are underdeveloped. Collaborative efforts, like the EU's ORCHID project, aim to establish validation protocols.[25]

4. Ethical and Commercial Considerations: Patient-derived models raise data privacy concerns, while commercialization requires cost-effective production. Startups like Emulate Inc. are pioneering scalable BoC kits for pharma.[23]

Conclusion

The BoC field is advancing rapidly, driven by interdisciplinary innovations in biosensing, AI, and biomaterials. Recent research has laid the groundwork for understanding bone mechanobiology, bone-cancer cross talk, while modular and patient-specific models are reshaping personalized medicine. Overcoming scalability and regulatory hurdles will be critical to unlocking the full potential of BoC systems in clinical applications.

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DATA-DRIVEN COMPUTATIONAL MODELING OF SOFT MATERIALS: AN EMERGING PARADIGM

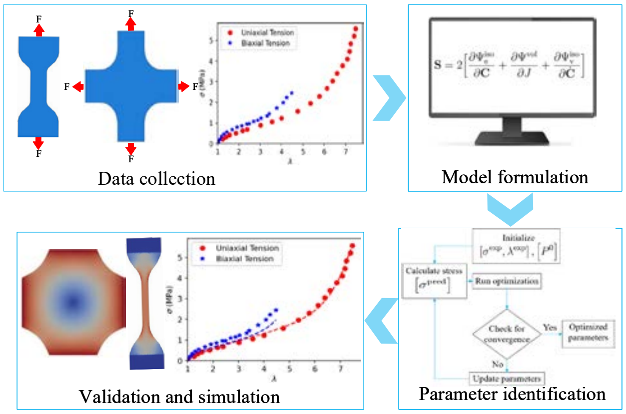

FIG. 1. CONVENTIONAL MODELING WORKFLOW. SYMBOLS AND DASHED LINES IN STRESS-STRETCH PLOTS REPRESENT EXPERIMENTS AND SIMULATIONS, RESPECTIVELY.

Introduction

SOFT MATERIALS, e.g. elastomers and hydrogels, have distinctive mechanical and functional characteristics that include large reversible deformations, nonlinear stress-strain relation, viscoelasticity, and biocompatibility. Thanks to these characteristics, they find extensive component applications in industries including biomedical, automotive, and flexible electronics. Designing such components requires accurate knowledge of mechanical behavior through experimental mechanical testing, especially nonlinear stress-strain relations and time-dependent responses. Experimental methods can be time-consuming, costly, or infeasible. With modern computational capabilities and the development of advanced finite element software, computational modeling is nowadays an integral part of the component design process, enabling the prediction of complex mechanical phenomena. The development process of a material model, the core of conventional modeling, involves defining mathematical expression and determining the unknown coefficients. This approach, in the realm of soft materials, has been in development since the 1940s.[1] It involves selecting a specific form of the strain energy density function (SEDF) and then determining the corresponding material parameters through optimization techniques. Conventional modeling includes micromechanical and phenomenological approaches. The former approach is physics-based and links the material's microstructure, such as polymer chain behavior, to its macroscopic mechanical response.[2] In contrast, the latter approach is empirical in nature as it describes the material's response through analytical functions without considering the underlying microstructure. The emergence of data-driven modeling provides a promising new paradigm for overcoming the limitations of conventional modeling.

Limitations of conventional modeling

The process of selecting an appropriate SEDF depends on the analyst's experience or availability of established models in literature that have shown acceptable predictive performance. After selecting a specific expression for the strain energy SEDF density function and obtaining the analytical expression of stress-strain relation, the next step involves applying an optimization technique to determine the parameters of the model. If the predictions of the model are not acceptable, the process must be repeated starting from selecting a different form of the SDEF expression. The steps involved in conventional modeling are illustrated in *Fig. 1*. The predictive accuracy of conventional models varies depending on the material, deformation level, and loading conditions. Given the vast number of analytical expressions of SEDFs existing in literature, selecting the right form and identifying optimal parameters is often a challenging and experience-driven task. Consequently, conventional modeling can be both tedious and time-consuming.

The data-driven paradigm

Data-driven approaches are recent developments that enable direct use of experimental data to construct stress-strain response without requiring a predefined form of SEDF. The steps involved in the data-driven approach are illustrated in *Fig. 2*. Compared to the conventional modeling, data-driven modeling replaces the steps of model formulation and parameter identification. In this case, a priori knowledge of specific forms of strain energy density expression is not needed. This eliminates the time-consuming and error-prone processes of model formulation and parameter identification. The concept of data-driven computing was introduced to the field of computational solid mechanics by Kirchdoerfer and Ortiz[3] through their approach known as distance-minimizing data-driven computing. In their framework, experimental data in the form of stress-strain pairs are directly utilized, and data-driven solvers are formulated to minimize the distance between the computed solution and the available data. Since the distance-minimization approach requires the development of entirely new data-driven solvers, it has not received as much attention as the other category of data-driven methods—the model-based approaches, such as artificial neural network-based and spline-based techniques—which can be more readily integrated into traditional finite element solvers.[4]

Neural network-based: Neural network-based modeling was first introduced to computational solid mechanics by Ghaboussi et al.[5]. Inspired by the human brain, where in-

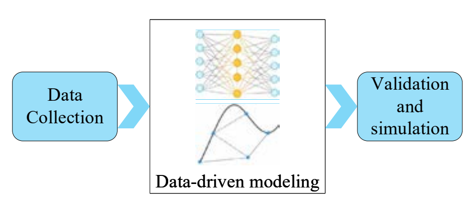

FIG. 2: DATA-DRIVEN MODELING WORKFLOW.

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terconnected neurons process information, artificial neural networks (ANNs) learn complex input-output relationships directly from data. They capture, for instance, stress-strain relations through training on experimental data and serve as surrogates for constitutive models, predicting stress from strain. ANNs also enable fast, cost-effective hyperelastic parameter identification, as shown by Yenigun et al.[6] Embedding physical laws into neural architectures yields Physics-Augmented Neural Networks (PANN), combining neural power with mechanics laws, as popularized by Raissi et al.[7] in Physics-Informed Neural Networks (PINNs). To demonstrate the predictive superiority of the data-driven modeling over conventional modeling, we chose the popular Yeoh model and compare its predictions with those of an ANN-based model presented by Hu et al.[8] for a Very High Bond (VHB) elastomer under uniaxial tension. The comparison is presented in *Fig. 3 (c)* and *(d)* where predictive accuracy is quantified using Normalized Mean Absolute Difference (NMAD), The data-driven method captures the complex stress-strain relation accurately with significantly lower error of 0.283 % compared to 3.986 % for conventional modeling.

Spline-based: Spline-based data-driven modeling builds a piecewise spline from experimental stress-strain data under different loading conditions. B-spline interpolations approximate derivatives of the strain energy function. First applied by Sussman and Bathe[9] for isotropic, incompressible soft materials, this approach enables flexible, accurate modeling without specific SEDF forms. Comparison of conventional (Yeoh) and spline-based model[4] in predicting the response of aneurysmatic abdominal aortas (AAA)[10] and vulcanized rubber[11] under equibiaxial loading is presented in *Fig. 3 (a)* and *(b)*, respectively. Indeed, the equibiaxial loading is challenging to describe using conventional m as demonstrated by both the stress-stretch curves and the NMAD values in *Fig. 3 (c)* where the data-driven approach posts more than threefold improvement in prediction accuracy.

Challenges and prospects

Driven by advanced computational capabilities, open-source computational tools, and increased availability of experimental data, data-driven methods of modeling material behavior have witnessed significant progress in recent years. This progress is accompanied by several challenges, one of which is difficulties in acquiring experimental data of high quality, particularly under complex loading conditions. Such data is often either expensive or time consuming to obtain. Low quality/noisy data leads to overfitting which is characterized by unrealistic model performance such as excellent fit to training data but failure to generalize to other loading scenarios. Physical laws like thermodynamic consistency and high-quality data from multiple loading modes are necessary for mitigating overfitting., Experiments concerning soft materials are susceptible to noise and boundary condition uncertainties, which can significantly affect the model accuracy. Furthermore, data-driven methods such as physics-informed neural networks (PINNs) can be computationally demanding, particularly when applied to three-dimensional large deformation problems under complex loading conditions. Current and future research efforts are expected to focus on the development of models that combine data-driven and physics-based approaches. These can result in improved methods for uncertainty quantification, and the establishment of standardized data sets.

Conclusion

The possibility of performing in-silico studies of soft materials directly from experimental data is very attractive and has potential of revolutionizing computational modeling of soft materials by offering a flexible and accurate approach rather than the complex conventional modeling that requires a priori knowledge of analytical expression of SEDF. The greatest advantage of data-driven approaches lies in eliminating the need for determination of an explicit analytical form of SEDF and its associated model parameters as these steps are error-prone and time-consuming.

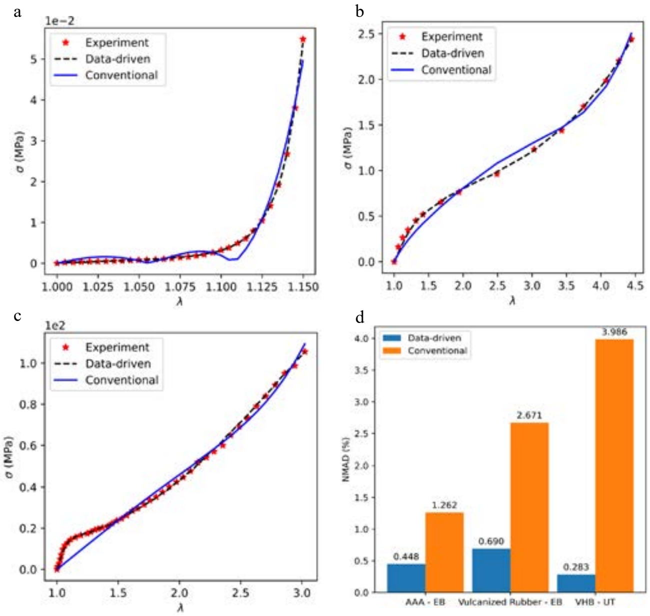

FIG. 3: FCOMPARISON OF PREDICTIONS FROM DATA-DRIVEN AND CONVENTIONAL MODELING AGAINST EXPERIMENTAL RESULTS FOR SOFT TISSUES INCLUDING (A) ANEURYSMATIC ABDOMINAL AORTAS (AAA) UNDER EQUIBIAXIAL TENSION (EB), (B) VULCANIZED RUBBER UNDER EB (C) VERY HIGH BOND UNDER UNIAXIAL TENSION (UT), AND (D) COMPARISON OF THE PREDICTIVE ACCURACY BASED ON THE NORMALIZED MEAN ABSOLUTE DIFFERENCE (NMAD) METRIC.

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ME NEWS & RESEARCH

HIGHLIGHTS

PHOTO: LAPAROSCOPIC SIMULATOR

TRAINING PAEDIATRIC SURGEONS WITH THE HELP OF ARTIFICIAL INTELLIGENCE

Laparoscopy is a minimally invasive surgical technique where thin instruments and a camera are inserted through small incisions into the abdominal cavity[1]. Compared to open surgery, laparoscopic procedures cause less trauma, enable faster recovery, and reduce hospital stays for patients.[1] However, unlike open surgery, surgeons rely solely on a 2D video feed to navigate the operation, requiring them to translate 2D visuals into 3D spatial awareness while mastering depth perception and hand-eye coordination.[2] These challenges are exacerbated in paediatric patients, where the significantly smaller surgical sites and fragility of the paediatric anatomy demand extreme precision.[3] To develop these fine motor skills, surgeons must practice laparoscopy outside the operating room. While physical simulators can provide a safe training environment, they are designed for adult patients and, currently, there is limited work in surgical simulators tailored specifically for paediatric patients. In addition, current training methods require an expert surgeon to be present and provide feedback to training surgeons.

In conjunction with the Children's Hospital of Eastern Ontario (CHEO) and SickKids, a team of graduate students, including Alec Cotton and Kade MacWilliams, led by Professors Carlos Rossa and James Green in the BioMechatronics Lab at Carleton University is creating a cyber-physical laparoscopy surgical simulator specifically designed for paediatric patients, and algorithms to provide real-time feedback to training surgeons without the need for an expert to be present. Building on a functional simulator developed at Carleton University, they are integrating machine learning and time-series algorithms that learn the surgical procedure from an expert surgeon, evaluate and score training surgeons, and teach them how to perform or improve a given procedure. Their algorithms can identify the surgical procedure being performed, assess the surgeon's proficiency level and identify the specific surgical task being executed. Combining a convolutional neural network with dynamic time warping and a k-Nearest Neighbour classifier, the algorithm also compares the surgeon's performance to a database to determine the surgeon's proficiency level.

This research will provide actionable feedback to training surgeons on their techniques. After assessing their performance, the team aim to translate complex metrics into clear, practical guidance. This involves breaking down surgical procedures into smaller segments, evaluating performance in each section as well as the entire procedure. By doing so, they can highlight specific areas for improvement to enhance overall surgical outcomes. The simulator and algorithms will be evaluated in a large-scale study at the CHEO and SickKids involving expert surgeons and residents.

Laparoscopic surgery, whether done traditionally or robotically, is shaping the future of surgical care. Combining physical simulators with automated evaluation will allow surgeons to become more proficient in a shorter duration and make laparoscopy training accessible in remote locations and developing countries. When an expert surgeon teaches the machine, and the machine teaches another surgeon, this system offers cost-effective knowledge transfer from leading experts in paediatric surgery to anyone, anywhere in the world. Eventually, more efficient laparoscopy training will reduce error rates and lower major complications and mortality in children who undergo the procedure.

— Technical Editor, Dr. Ali Hosseini, MCSME

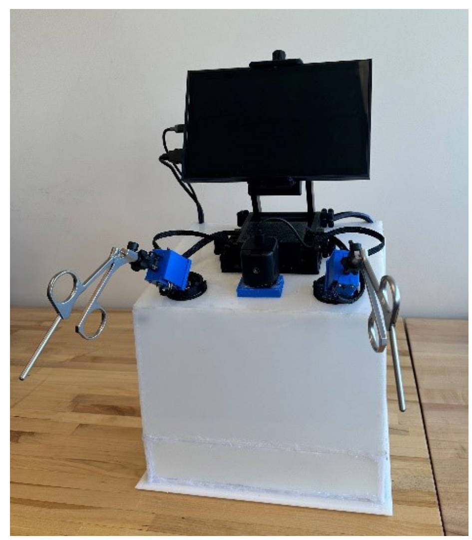

PHOTO: TRADITIONAL PAEDIATRIC LAPAROSCOPIC SIMULATOR

IMAGES COURTESY OF THE RESEARCHERS

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Tumoroid-On-a-Plate (ToP): Physiologically Relevant Cancer Model Generation and Therapeutic Screening

Three-dimensional (3D) cell culture models are vital for testing drug efficacy in vitro during the drug development process. Innovative fabrication techniques have been developed to produce consistent and large batches of multicellular spheroids (MCS) or organoids, offering a promising alternative to the high costs and predictive limitations associated with animal testing and traditional monolayer, or "2D," in vitro cultures. Compared to these 2D cultures, 3D models more accurately replicate the cellular microenvironment, intercellular communication, drug response, and structural features of in vivo tissue, which is crucial when advancing to animal testing and clinical trials. Furthermore, these models can achieve greater complexity and physiological relevance by incorporating various bioengineered extracellular matrices (ECM). 3D in vitro models that incorporate ECM create biomimetic environments that simulate the signaling processes involved in cell-to-cell and cell-to-ECM interactions, thereby providing structural and biochemical support for the growth and maturation of tumor organoids. Basic 3D tumor models utilizing spheroids can be developed from a wide variety of adherent cell types, including those derived from patient tumors and cancer cell lines. These spheroids are formed through the self-organization and intercellular linking of cancer cell lines.

Various techniques are available for creating multicellular spheroids using non-cell adherent substrates, such as soft lithography, 3D printing (stereolithography), injection molding, and thermoforming microwells. Among these, hydrogel microwells produced through 3D printing stand out for high-throughput drug testing due to their precision, adaptability, and cost-effectiveness. Current hydrogel-based microwell arrays face challenges in accurately recreating the complete tumor microenvironment, including elements like the ECM and stromal compartments. Consequently, there is a significant need for a new platform that can address these limitations and offer a more comprehensive model of the tumor microenvironment.

To address these challenges, a team of researchers in the Laboratory for Innovations in Micro Engineering (LiME), Department of Mechanical Engineering, University of Victoria, led by Professor Mohsen Akbari, presented a Tumoroid-on-a-Plate (ToP) device, a novel open-surface microfluidic platform crafted to develop predictive 3D models of solid tumors. The ToP device integrates tumor mass, stromal cells, and ECM components to closely mimic the microenvironment of glioblastoma (GBM) and pancreatic adenocarcinoma (PDAC). By utilizing the advanced ToP model and experimenting with various GBM ECM compositions, such as collagen and Reelin, the study evaluates the impact of specific elements on GBM invasiveness. The ToP in vitro model also facilitates the screening of chemotherapeutics like temozolomide and iron-chelators, in a single and binary treatment setting, on ECM-embedded tumoroids, assessing their toxicity concerning the viability and apoptosis of GBM and PDAC models. Moreover, co-culturing PDAC tumoroids with human-derived fibroblasts highlights the pro-invasive effects of stromal elements on tumor growth and drug response. This research highlights the significance of advanced 3D models like ToP in enhancing our understanding of cancer complexity and therapeutic responses. *— Technical Editor, Dr. Ali Hosseini, MCSME*

Reference article:

Seyfoori, Amir, Kaiwen Liu, Hector J. Caruncho, Patrick B. Walter, and Mohsen Akbari. "Tumoroid-On-a-Plate (ToP): Physiologically Relevant Cancer Model Generation and Therapeutic Screening." *Advanced Healthcare Materials* 14, no. 1 (2025): 2402060.

SOFT HAND EXOSKELETON WITH SITUATIONAL AWARENESS AND GRIP FORCE CONTROL

Stroke survivors often experience residual disability after their stroke and receive insufficient therapy and everyday assistance to live independently and maintain their quality of life. Soft exoskeletons have the potential to provide assistance throughout everyday life in a comfortable and easy to use manner and motivate the user to incorporate their affected limb to stimulate motor recovery. However, open multidisciplinary challenges restrict the usability and availability of these systems. Funded by NSERC, CIHR, Canadian Partnership in Stroke Recovery, Toronto Rehabilitation Institute, IC-IMPACTS NCE and AGE-WELL NCE, a team of researchers including Daimen Landori-Hoffmann and led by Professor Aaron Yurkewich and Professor Meaghan Charest-Finn at Ontario Tech University utilizes an iterative user-centered design process to create and evaluate soft hand exoskeletons with stroke survivors and their therapists and caregivers to uncover their needs and refine system design. This has led to the development of the Hand Extension Robot Orthosis (HERO) Glove, an open-source soft hand exoskeleton that can be integrated into in-clinic and at-home therapy programs to enable independence and increase use of the affected limb. User feedback has motivated the development of a new iteration, HERO Glove Insight, which provides greater grip force and object-specific grip force control.HERO Glove Insight integrates new mechatronic features such as 3D-printed anchoring structures, fingertip force sensors and a web camera. Mechanical improvements include custom mounting brackets and fishing line routing for better grip force. The YOLO V3 object detection and classification algorithm is used to provide situational awareness. A force sensing resistor (FSR, Tekscan A101) placed on the thumb measures the grip force. A cascaded computer vision-driven Proportional Integral Derivative (PID) algorithm provides accurate grip force control based on pre-defined object-specific grip force targets. The system showed a 55% increase in grip strength, with force control accurate to within 1 Newton. The computer vision system achieved approximately 98% accuracy in object identification.

HERO Glove Insight helps users to hold objects with a safe and consistent amount of force, regardless of how much grip force the user can provide to the task. In future works, the team aims to investigate controllers that reward user engagement and integrate this system into clinical trials with stroke survivors to evaluate its usability and effect on their independence and motor recovery. *— Technical Editor, Dr. Ali Hosseini, MCSME*

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Université de Sherbrooke Dr. Céderick Landry

Wearable Cardiovascular Health Technologies

Heart disease is the leading cause of death globally, with hypertension responsible for nearly half of these fatalities.[1] Conversely, low blood pressure (BP), particularly in older adults, increases the risks of injurious falls[2], showcasing the urgent need for better solutions to monitor and manage BP.

Semi-Cuffless BP Monitoring: Unlike traditional cuff-based BP monitors, most cuffless BP monitoring techniques allow for continuous measurement of BP, which provides a more complete picture of the patient's condition. Despite the clearance of some cuffless BP devices by regulatory bodies, Hypertension Canada and the European Society of Hypertension do not currently recommend their clinical use due to accuracy issues and lack of robust validation.[3,4] Dr. Landry's research pioneers semi-cuffless BP monitoring, balancing accuracy with usability to improve hypertension management.

Dr. Landry's current smart Ambulatory Blood Pressure Monitor (ABPM) project is a pivotal first step toward achieving the broader objectives of his research program. Traditional ABPM devices measure BP every 20 minutes during the day and every 30 minutes at night, disrupting daily activities and sleep with every cuff inflation. The smart ABPM integrates a wrist cuff with wearable sensors, including accelerometers to track wrist position and photoplethysmography to trigger BP measurements only when detecting significant changes through an uncertainty algorithm.[5] The goal of the smart ABPM is to reduce discomfort by reducing the frequency of measurements, while maintaining diagnostic accuracy.

Though not designed for continuous BP monitoring, the smart ABPM lays the groundwork for opportunistic BP measurement. The long-term goal is to integrate sporadic BP measurement for opportunistic online BP model retraining for accurate and continuous BP measurement, advancing on previously developed subject-specific BP modeling using machine learning.[5–8]

Wearable Compression for Orthostatic Hypotension: Orthostatic hypotension (OH) — lightheadedness caused by a sudden BP drop upon standing, due to blood redistribution into the legs — contributes to decreased stability and balance, consequently increasing the risk of injurious falls. Dr Landry's research explores wearable compression devices to counteract OH by promoting blood flow back to the heart through timed compression of the lower limbs.

Previously developed intermittent pneumatic compression devices, which compress the legs in sync with heartbeats, showed promise in preventing BP drops.[9,10] While effective, the system required a stationary air compressor, limiting real-world use. The proposed system replaces bulky air compressors with electromechanical actuation. Using magnetorheological clutches, the device tightens segmented compression bands at targeted times to maximize benefit. This approach reduces weight and increases portability while maintaining the necessary compression power. Key challenges include optimizing compression timing and control strategies for precise pressure distribution independently from leg properties. The long-term goal is to trigger compression only when OH is detected through the semi-cuffless BP device, see *Figure 1*.

Vision: Dr. Landry's research envisions a future where wearable technologies seamlessly integrate into daily life, improving management and prevention of cardiovascular diseases. By bridging the gap between medical-grade and consumer wearables, his work aims at improving cardiovascular health through a multidisciplinary approach, involving engineers, clinicians, and physiologists to ensure these technologies are both technically robust and clinically relevant.

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CÉDERICK LANDRY, PhD, P.Eng.

Dr. Landry is an Assistant Professor of Mechanical Engineering at Université de Sherbrooke and researcher at the Research Center on Aging (Centre de recherche sur le vieillissement – CdRV). *He received his PhD in the Mechanical and Mechatronics Engineering Department at the University of Waterloo in 2021 and was a Postdoctoral Associate for two years in the Bioengineering Department at the University of Pittsburgh. His research lies at the intersection of mechatronics engineering, artificial intelligence, and cardiovascular physiology. Dr. Landry's research focuses on wearable solutions for vital signs monitoring and management, aiming to improve prevention and treatment of cardiovascular diseases.*

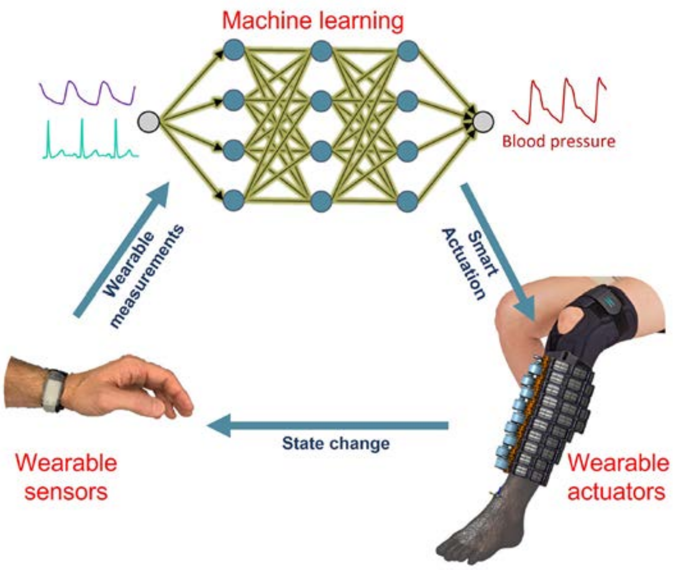


FIG. 1: A CLOSED-LOOP BLOOD PRESSURE MANAGEMENT SYSTEM TO REDUCE PRESSURE DROPS THAT LEAD TO FALLS. THE SEMI-CUFFLESS BP TECHNOLOGY DEVELOPED BY DR. LANDRY, WHILE CLINICALLY MEANINGFUL FOR HYPERTENSION MANAGEMENT, IS USED TO DETECT BLOOD PRESSURE DROPS TO ACTIVATE THE WEARABLE ACTUATORS.

Western University
Dr. Elli Gkouti

Smart Materials, Smarter Future: Advancing Composite Microstructure Performance with AI

Dr. Gkouti is an Assistant Professor at Western University and her research is dedicated to advancing composite materials by merging physics-inspired modeling with state-of-the-art AI techniques to develop innovative composites and smart materials.

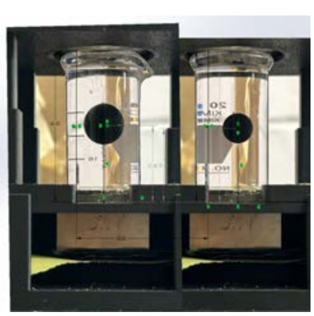
Motivation & vision: Modern industries—from aerospace to biomedicine—demand high-performing, resilient, and smart materials. Research in ***Dr. Gkouti Smart Material lab*** is driven by the challenge of uncovering and harnessing the intricate role of microstructural features in governing material behavior, while capturing composites' complex, interdependent physical responses through advanced multi-physics modeling. By exploring how microstructure affects overall mechanical performance and integrating AI with multi-physics simulations, Dr. Gkouti and her team design materials capable of predicting and preventing failures before they occur, enabling real-time defect detection, quality control, and autonomous failure prediction.

The work done at Dr. Gkouti Smart Materials lab underscores how microstructural control can enhance key mechanical properties. Her current research focuses on ***magneto-active composite materials*** and the development of a comprehensive framework for the fabrication, modeling/simulation, and intelligent control of smart composites. Likely applications for these magneto-active composite materials include adaptive vibration absorbers (e.g., tunable stiffness devices for aerospace structures), soft robotic actuators (e.g., systems capable of fast, reversible shape changes and remote-controlled motion) and wearable biomedical devices (e.g., heat-free shape-morphing implants or therapeutic patches). Their ability to rapidly adjust mechanical properties under magnetic fields makes them ideal for environments requiring real-time adaptability, precision and energy efficiency. In addition, using artificial neural networks[1], physics-informed neural networks and transfer learning, it is possible to optimize parameters such as particle size, phase distribution and defect density to boost stiffness, strength, toughness, and fatigue resistance. This microscopic fine-tuning translates into improved load-bearing capacity and energy dissipation at the macroscopic level.

ELLI GKOUTI, PhD

Dr. Gkouti is an Assistant Professor in the Department of Mechanical & Materials Engineering at Western University. She holds an Engineering Diploma and a master's degree in Applied Mechanics, while her doctoral research focused on analyzing elastic interactions between phase transformations and inhomogeneities within composite materials. Prior to joining Western University, Dr. Gkouti worked as a Research Associate and Postdoctoral Fellow at York University, specializing in experimental characterization and computational analysis of soft and elastomeric material behaviour. She is a member of the Technical Committee on Solid Mechanics of CSME and an Associate Editor of TCSME. *Her current research focuses on improving the performance of advanced composites and smart materials by utilizing physics-inspired models to account for their microstructure and integrating AI-driven methods for material fabrication and multi-scale characterization.*

Her research in composite materials includes improving ***Carbon Fiber Reinforced Polymers*** (CFRP) performance[2] as well as the development of ***dielectric smart material-based sensors***.[3] Recognizing that micro-scale defects—such as cracks, delamination, and voids—can critically compromise tensile strength and fatigue life, she employs advanced finite element analysis alongside AI-driven defect detection techniques (using CNNs, PINNs, and transfer learning) to create polyvinylidene fluoride or polyvinylidene difluoride (PVDF)-based strain sensors. The sensors are primarily designed to sense dynamic strain induced by mechanical vibrations and damage evolution within the composite structures. As the composite undergoes deformation due to external loads or defects (such as scratches, holes, and cuts), these strain changes generate electrical signals in the piezoelectric PVDF layer, which are then used for real-time detection and classification of faults. The sensors are embedded within the composite laminates or on the inner surface of the structure, allowing direct, high-sensitivity capture of structural strain variations with minimal interference from environmental noise. In addition, Dr. Gkouti's team have recently developed a **Magnetic Levitation tool** (*image below*) for a preliminary quality check of composite or polymer samples, where the specimens are subjected to a paramagnetic liquid solution (e.g., MnCl2) and an external magnetic field is applied. The specimen then levitates based on the Magneto-Archimedes principle and the measured levitation distance provides the density of the specimen, offering preliminary indications of the sample's quality against possible defects.[4]



Inspired by the advances of AI in fabrication, Dr. Gkouti and her group are also using ***intelligent manufacturing*** techniques that integrate optical imaging, data processing, and real-time feedback. Currently, Dr. Gkouti is working on projects related to developing metamaterials with tunable properties. She is also exploring 3D bioprinting under microgravity conditions to optimize elasticity, yield strength, and interlayer bonding, ensuring dimensional accuracy, uniform properties, and long-term reliability.

Anticipated impact: Dr. Gkouti and her team strive to efficiently link and control microstructural features with the macroscopic behavior, which will enable the development of robust and energy-efficient materials, enhancing safety and reliability in applications ranging from transportation and construction to biomedical devices. Dr. Gkouti is looking forward to collaborating with the CSME community and contributing to materials science and solid mechanics with modern AI technologies, transforming innovative research into tangible solutions that benefit society.

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University of Calgary
Dr. Taisiya Sigaeva

Soft Tissue Biomechanics: Stretching from Aorta to Skin

Skin, internal organs, the cardiovascular system, and other soft biological tissues exhibit distinctive mechanical behaviors: they respond to applied forces non-linearly, withstand large deformations, and display anisotropic properties governed by complex and inhomogeneous microstructures. Understanding soft tissue biomechanics through modeling and mechanical characterization is essential for studying tissue growth, development, normal and pathological function, and response to damage and aging. These insights are critical for improving patient diagnosis, treatment, and care, as well as guiding the development of new materials, biomedical devices, and technologies.

Dr. Sigaeva's research focuses on advancing state-of-the-art methodologies for the mechanical characterization and modeling of soft biological tissues (see *Figure* for a typical workflow).

Dr. Sigaeva's lab, shared with her longtime collaborator Dr. Elena Di Martino, is equipped with several biaxial tensile testing machines and a multi-axial mechanical tester capable of 3D indentation, friction, shear, torsion, and uniaxial tension loading modes - optimized for soft tissues (with max load 0.5-25 N) and smaller samples (with max dimension 5-30 mm). Dr. Sigaeva has contributed to the field of biaxial testing commonly used to model soft planar tissues by working to standardize biaxial protocols[1] and plans for her research group to subject the same tissue to multiple loading regimes sequentially for a more comprehensive mechanical characterization. Additionally, her group has access to multiphoton microscopy, which they plan to integrate with mechanical testing to observe the deformed microstructure. She will further use this information to improve constitutive modeling for a better understanding of tissues' behaviour, as she has done in the past, for instance, by applying worm-like chain models to understand the contribution of heterogeneous elastic lamellae to aortic homeostasis.[2]

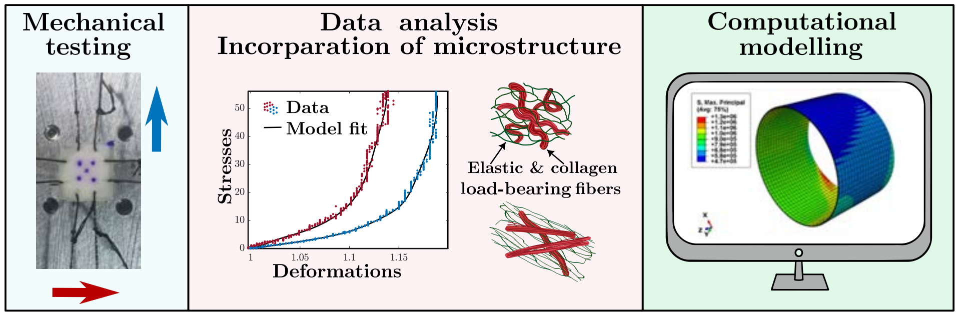

FIGURE: SOFT TISSUE BIOMECHANICS WORKFLOW.

Aortic Aneurysm Biomechanics

One of the main research directions of Dr. Sigaeva's group is the study of aortic aneurysms - dangerous enlargements of the aorta caused by mechanical degradation of its walls. Using biaxial experiments and constitutive modelling, Dr. Sigaeva has demonstrated that this degradation is heterogeneous, affecting stress distribution along the vessel and potentially serving as a mechanical stress-related biomarker.[3] Her team is currently working on computational modeling of mechanical heterogeneity using the functionally graded material model approach. They are also investigating the role of other factors accompanying the localised mechanical degradation such as calcification, using both experimental and imaging techniques. These projects are aimed at improving understanding of aneurysm progression and informing better management strategies.

Skin and Wound Biomechanics

Another key focus of Dr. Sigaeva's research group is the biomechanics of skin and wound healing. She and her collaborators were among the first to conduct biaxial testing of wounded skin in an equine model, quantifying the mechanical impact of treatment on skin regeneration.[4] Dr. Sigaeva's work continues to explore the mechanical properties of both healthy and wounded skin using a combination of experimental and imaging techniques to better understand heterogeneity, normal function, healing, and aging. She hopes that her group's research will contribute to advancements in skin health, regeneration and wound treatment.

For possible supervision or collaboration opportunities, please contact Dr. Sigaeva at taisiya.sigaeva@ucalgary.ca.

TAIS SIGAEVA, PhD

Dr. Sigaeva earned her PhD in Mechanical Engineering from the University of Alberta in 2015. She then held postdoctoral positions at York University and the University of Calgary. In 2020, she joined the Systems Design Engineering Department at the University of Waterloo as an assistant professor. In 2023, she returned to the University of Calgary as an assistant professor in Departments of Mechanical and Manufacturing Engineering and Biomedical Engineering, drawn by collaborations in the skin and cardiovascular mechanics within the Schulich School of Engineering, Cumming School of Medicine, and Faculty of Veterinary Medicine. Dr. Sigaeva's research is funded by the Natural Sciences and Engineering Research Council, Canada Foundation for Innovation, and Government of Alberta/ Alberta Ministry of Technology and Innovation.

IMAGES COURTESY OF THE RESEARCHER

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McMaster University
Dr. Keena Trowell

Solid and circular: metal fuels for energy storage and hydrogen production

Addressing climate change is a defining challenge of our era. Rising concentrations of greenhouse gases in our atmosphere is driving extreme weather events and disrupting an increasingly large portion of the global population. In Canada alone, the 2023 wildfires displaced over 167,000 people. Energy derived from the combustion of hydrocarbons is responsible for two-thirds of greenhouse gas emissions.[1] A widespread adoption of sustainable low carbon technologies is required to arrest climate change. Although renewable power technology is maturing, and renewable potential is more than adequate to meet demand, the lack of long–duration energy storage has hindered the transition to a low–carbon energy system.

Dr. Keena Trowell and her team at McMaster University see metals, especially aluminum, as a promising, circular energy vector to address this gap.[2] Aluminum is abundant, and safe to store and handle. The metal is produced wherever (and whenever) there is an abundance of clean power. Modern aluminum smelters have an efficiency around 62%. This means that 62% of the electricity going into the smelter is stored as “solid electricity” in the form of aluminum. This is comparable to water electrolysis processes used to produce hydrogen.

When the stored energy is needed, the aluminum is reacted with water to produce hydrogen and heat, on–site and on–demand. Aluminum is an excellent fuel for metal-water systems because it produces large amounts of hydrogen (approx. 1200L of hydrogen per kg of Al) and has twice the energy density of diesel. The oxides produced in the reaction can be stored for eventual recycling. Each liter of aluminum produces the equivalent of 4L of liquid hydrogen and heat equivalent to burning 1L of diesel. Dr. Trowell has demonstrated full conversion of aluminum and water to heat and hydrogen. Using the high-temperature process pioneered by Dr. Trowell, a cycle efficiency (power–to–power) of 25% is possible (compared to approximately 20% for hydrogen or 15% for ammonia.[3]

Most of the research in the field of metal-water reactions has focused on developing catalysts to enable the oxidation reaction to proceed at low temperatures. The main challenge is to overcome the naturally–occurring passivating oxide layer on the surface of aluminum. Dr. Trowell’s pioneering, patented approach takes advantage of the changing polarity and ionic concentration as the water reaches its critical point.[4] It is also believed that the solubility of the passivating oxides/hydroxides formed by the reaction increase under supercritical conditions allowing for the full oxidation of large (mm-scale) pieces of metals.

Dr. Trowell is leading several parallel projects on the topic of supercritical water oxidation of metals to further the understanding of the fundamental nature of this reaction. There are several open research questions being explored including the role of the hydrogen bonding network present in water, as well as decoupling the effects of pressure and oxidizer concentration in the reaction chamber. Her lab is equipped with bespoke, high–temperature, high–pressure reactors to run experiments under extreme conditions. The experimental work is complemented by imaging techniques (SEM, TEM) as well as numerical studies.

On the application side of the research spectrum, Dr. Trowell’s team is looking at developing reactors and heat exchanger networks that can take advantage of the extreme exothermic nature of the reaction. The challenge lies in pulling enough heat from the reactor in order to maintain the desired super critical conditions.

KEENA TROWELL, PhD

Dr. Trowell is an assistant professor in the Department of Mechanical Engineering at McMaster University since 2022. She earned her PhD at McGill University as a Vanier scholar. Her research interests include metal fuels, energy storage, energy for remote regions, the water–energy nexus, and the techno–economic analysis of circular fuels. She holds a patent on a method to produce hydrogen through supercritical water oxidation and has published several papers on the topic.

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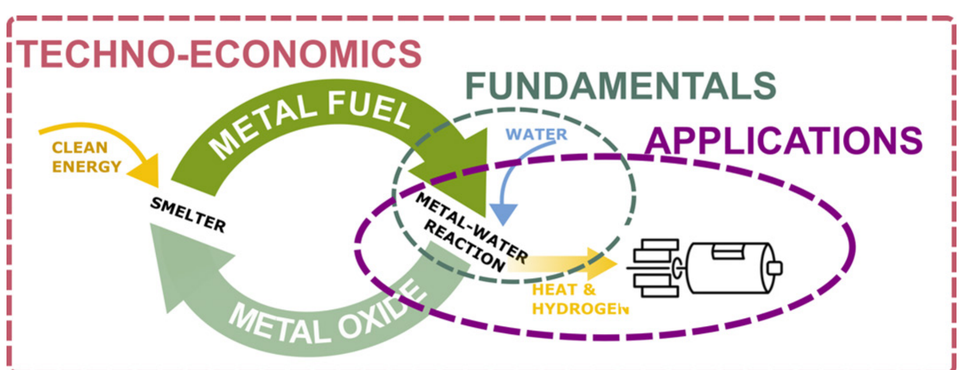


FIG. 1: A SNAPSHOT OF DR. TROWELL'S RESEARCH PROGRAM. HER AND HER TEAM ARE RESEARCHING THE FUNDAMENTAL NATURE OF SUPERCRITICAL WATER REACTIONS, THEIR POTENTIAL APPLICATIONS IN ENERGY, AND THE TECHNO-ECONOMICS OF NOVEL ENERGY SYSTEMS.

Q & A

ALIREZA NOAMANI, PhD

Dr. Noamani has a PhD in Mechanical Engineering from the University of Alberta, specializing in the development of wearable technologies. His technical background includes analysis of dynamical systems, sensor fusion, control theory, and machine learning.

Dr. Noamani has extensive experience in conducting experimental studies in different settings, including human motion laboratories and clinical settings. His primary research interest is algorithm development for continuous health monitoring using wearable sensors. He has developed and implemented analytical and AI-based algorithms for various applications, including human activity recognition, gait analysis, fall detection, fall risk assessment, energy expenditure estimation, balance assessment, and sleep analysis.

Currently, Dr. Noamani is a Data Scientist at Myant Inc., where he develops algorithms and end-to-end AI pipelines for continuous health monitoring. Before this, he was a member of the Neuromuscular Control and Biomechanics Laboratory at the Mechanical Engineering department of the University of Alberta. His PhD research involved applying nonlinear control theory, online system identification, optimal estimation, and machine learning to develop novel algorithms for wearable and assistive technologies used for health monitoring and analyzing neuromuscular systems.

Q: Do you think the new advances in wearable technology will contribute to improving healthcare and quality of life in Canada?

Absolutely, I'm quite optimistic about how recent developments in wearable technology can really make a difference in healthcare and everyday life here in Canada. What's exciting is how these devices are getting better and smarter at continuously collecting important health data outside of traditional clinics. We're talking about a constant read on heart health, oxygen levels, as well as detailed information about movement, sleep, and stress.

Integrating AI is crucial here. It helps us make sense of all this data. Algorithms are getting smarter at spotting subtle patterns that might signal a health issue early, sometimes before any symptoms even show up. This can help us predict risks. Plus, Generative AI offers exciting possibilities for personalized health feedback tailored to someone's specific data profile.

Considering Canada's size and scattered population, wearables offer a fantastic way to connect people in remote areas to healthcare through remote monitoring. This kind of continuous oversight supports managing health proactively. My hope is that this can help ease the pressure on our healthcare system and truly empower Canadians to be more involved in their own health. It feels like a real step towards healthcare that's more personal, preventative, and accessible for everyone.

Q: What are the most important advancements in the area of wearable technology over the past decade?

Reflecting on the past ten years, I'd say the most impactful changes in wearable technology are improvements in sensors, how we process the data, and crucially, the integration of AI.

We've seen sensors become much smaller, more power-efficient, and capable of capturing a wider range of reliable physiological signals. For example, optical sensors for heart rate, electrodes for more accurate ECGs, and motion sensors that give us incredibly detailed movement data. Their improved performance has made continuous, long-term monitoring in user-friendly devices feasible.

A major step forward has been embedding more sophisticated AI, specifically machine learning, either within the wearables themselves or in their connected platforms. Early devices were mostly about raw data. Now, they use machine learning to interpret that data automatically. For example, analyzing sleep stages, estimating fitness levels, inferring stress, or analyzing gait patterns to help identify conditions or assess fall risk.

Also, using advanced AI like deep learning has allowed for even deeper analysis, picking up on complex patterns that might indicate subtle health changes. Although Generative AI is still relatively new in consumer applications, it's starting to show potential for creating personalized user feedback. The real transformation, in my view, is this shift from simple data collection to intelligent, context-aware analysis. That's what has really turned wearables into powerful tools for personal health insights and preventative care.

Q: What inspired you to pursue a career in biomechanics and healthcare technology?

My career path in data science for healthcare technologies was really driven by two key interests: a deep fascination with the biomechanics of the human movement and a strong desire to apply engineering skills to improve health and quality of life.

Biomechanics offers a way to understand and precisely analyze human movement. Seeing how technology, like assistive devices or rehabilitation tools, could make a real difference made me more interested. Then, the rise in sensor technology, computing power, and data science, especially AI, felt like this incredible opportunity aligning perfectly with my goals. Combining these AI advancements with biomechanical principles means we can create sophisticated wearable systems that can objectively and continuously monitor physiological and biomechanical health in everyday lives.

Frankly, the idea of developing intelligent wearable devices is what truly excites me. This combination of engineering, data science, AI, and applying it directly to healthcare is, I believe, where the future is headed, and it's the core inspiration behind my career choice.

Q: Why does your industry sector collaborate with academics? What are the benefits?

In healthcare technology, and especially in areas like biomechanics and wearable health monitoring, partnering with academic institutions is really essential, not just beneficial. It works so well because our expertise is very complementary. Universities bring deep scientific knowledge, foundational research, physiological expertise, and the rigorous methods needed for validation and clinical studies. Industry, on the other hand, is focused on product development, scalability, regulations, market needs, and actually getting the technology into the hands of users. This practical side makes sure that innovative ideas are not only scientific but also feasible, user-friendly, and solve real-world clinical or wellness problems.

This collaboration has significant benefits. It accelerates taking scientific ideas and innovations and turning them into actual products and services that can help patients. Industry gains access to new ideas and talent. Academia benefits from practical insights, resources for studies, and seeing their research make a direct impact.

...continued on page 28

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

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

NEWS COMMUNIQUÉ

April 2025

The Canadian Society for Mechanical Engineering (CSME), founded in 1970, is pleased to announce the winning recipients of its 2025 regular awards. These awards may be bestowed to members of the society for their outstanding contributions to specific areas of mechanical engineering in Canada.

In addition to the three previously announced 2025 technical award winners, seven exceptional engineers will be presented with regular society awards during the 27 May banquet of the 2025 CSME International Congress to be hosted on 26-28 May by the École de technologie supérieure, Montréal, QC.

Please consider attending the 2025 CSME International Congress to congratulate all of these exceptional award winners and network with colleagues: www.csmecongress.org.

Clifford N. Downing Award

For "distinguished service to the CSME over many years"

Jerzy Maciej Floryan, PhD, FCSME
Western University, London, ON

I.W. Smith Award

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

Cuiying Jian, PhD, MCSME
York University, Toronto, ON

2025 Industrial Innovation Award

For "outstanding contributions to innovations in industry within mechanical engineering in Canada"

Serge Lalonde
Pratt & Whitney, Longueuil, QC

2025 CSME Fellows

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

Martin Agelin-Chaab, PhD, FCSME *(2025)*
Ontario Tech University, Oshawa, ON

Hamid Akbarzadeh, PhD, FCSME *(2025)*
McGill University, Montreal, QC

Tobin Filleter, PhD, FCSME *(2025)*
University of Toronto, Toronto, ON

John Wen, PhD, FCSME *(2025)*
University of Waterloo, Waterloo, ON

Clifford N. Downing Award

Dr. Jerzy Maciej Floryan

Professor Jerzy M. Floryan is Professor at the Department of Mechanical and Materials Engineering at the University of Western Ontario. His research focuses on fluid mechanics, particularly in relation to the reduction of pressure losses associated with fluid transportation.

Professor Floryan has served the engineering community consistently and very well for many years. As CSME President from 2018 to 2020, he modernized its operations, stabilized and increased the membership base, established the organizational framework for the yearly Congresses and initiated the annual publication of the *Progress in Canadian Mechanical Engineering*. As a Canadian representative to the International Union of Theoretical and Applied Mechanics (IUTAM), he increased the Canadian role in this organization and brought the 23rd International IUTAM Congress to Canada.

Professor Floryan is a Fellow of many societies and distinguished organizations, including the CSME, the ASME, the JSPS, the CAE, and the EIC, among others.

I.W. Smith Award

Dr. Cuiying Jian

Dr. Cuiying Jian is an Associate Professor in the Department of Mechanical Engineering at the Lassonde School of Engineering at York University. She is a trailblazer in the development of green applications for carbon-intensive materials in energy storage and wastewater treatment through laser-assisted manufacturing.

Dr. Jian has authored more than 30 publications and is the recipient of the 2024 Petro-Canada Emerging Innovator Award. She is committed to promoting equity, diversity, and inclusion (EDI) within the Lassonde community and the mechanical engineering profession. At York, Dr. Jian currently serves as the Graduate Attribute Lead for engineering accreditation and leads a project focusing on integrating EDI principles into the MECH curriculum. She also chairs the EDI Committee of the CSME.

Industrial Innovation Award

Mr. Serge Lalonde

Mr. Serge Lalonde is a Pratt & Whitney Fellow and a leading figure in the field of failure analysis of aerospace components. Over the last 40 years, he has done or participated in more than a thousand failure analyses and materials behaviour cases. He has brought innovative methods to industry that have allowed accurate determination of the root causes of failures which have resulted in the development of new manufacturing techniques, more resilient alloys, and elevated safety standards within the aerospace industry.

Mr. Lalonde's untiring dedication and passion to using advanced theoretical and experimental tools has positioned him as a vanguard in understanding the complex interactions between Design-Manufacturing Process-Material- and Service Properties, that are at the origin of failures in the very harsh working environment of an aircraft engine, making him a deserving inaugural recipient for CSME's Industrial Innovation Award.

CALL FOR 2026 CSME and EIC AWARD NOMINATIONS

Nominations are now open for the next round of technical and regular awards from the Canadian Society for Mechanical Engineering (CSME), recognizing outstanding professionals in mechanical engineering: csme-scgm.ca/awards. Nominations are also invited for the 2026 Engineering Institute of Canada (EIC) awards: eic-ici.ca/honours_awards/nomination.

CSME Award Guidelines: Final decisions are made by the CSME Awards Committee (President, Immediate Past President, and Senior VP). Self-nominations are not allowed. Except for the Industrial Innovation Award, nominations must be submitted by CSME Fellows. Members can only win each award once. At all times, the name of nominees and nomination cases should be kept confidential and never be shared with other nominees or the public.

Deadlines:
CSME Technical Awards (Fluid Mechanics, Solid Mechanics, Manufacturing): 30 Sept 2025
CSME Regular Awards: 31 Jan 2026
EIC Awards: 15 Nov 2025

Fellow

Dr. Agelin-Chaab

Dr. Martin Agelin-Chaab is a Professor of Mechanical Engineering at Ontario Tech University and Chair of its Mechanical and Manufacturing Engineering Department. Martin has made significant scholarly contributions to thermofluids and energy systems with over 250 peer-reviewed contributions, including 6 book chapters and 7 patents pending. He has collaborated with industry partners to develop innovative thermal management and advanced sensor soiling mitigation strategies.

Martin has served as an associate editor for the Transactions of the Canadian Society for Mechanical Engineering (CSME) from 2015 to 2017 and since 2019. He also serves on the editorial board of multiple international journals. Finally, Martin served as the Chair of the Fluids Mechanics Engineering Technical Committee of the CSME from 2019 to 2023 and, in that capacity, co-organized several Fluid Mechanics symposia of the CSME International Congress and chaired many sessions.

Fellow

Dr. Akbarzadeh

Professor Hamid Akbarzadeh is a Canada Research Chair and an Associate Professor in the Bioresource Engineering Department at McGill University. He is also the Director of Advanced Multifunctional and Multiphysics Metamaterials Lab (AM3L) at McGill and is serving as the Chair of CSME's Technical Committee on Solid Mechanics.

Hamid's research and training program at AM3L is aligned with systematic design, multiscale multiphysical modeling, and 3D printing of reprogrammable and smart multifunctional metamaterials and metastructures. To date, his contributions have led to 8 patents (application or provisional) and reports of inventions, and 140 articles published in high-impact journals, such as Advanced Materials, Advanced Functional Materials, Advanced Science, Nature Communications, ACS Nano, Nano Energy, and Energy Storage Materials.

Fellow

Dr. Filleter

Dr. Tobin Filleter is currently a Professor in the Department of Mechanical & Industrial Engineering (MIE) at the University of Toronto. Tobin received a B.Sc. in Engineering Physics from Queen's University (2003) and PhD in Physics from McGill University (2009). Prior to joining MIE, he was a postdoctoral research fellow in the Department of Mechanical Engineering at Northwestern University (2009-2012).

Professor Filleter's research interests are in nanomechanics of materials. Specific areas of research include nanotribology, mechanics of 2D materials, nanocomposites, and non-destructive testing. He has authored papers in many top international journals including Nature, Science, Nature Materials, Science Advances, and Nature Communications. He is the recipient of several major awards including the CSME I.W. Smith Award and CSME Solid Mechanics Medal, the Erwin Edward Hart Professorship, NSERC Synergy Award, and Ontario Early Researcher Award.

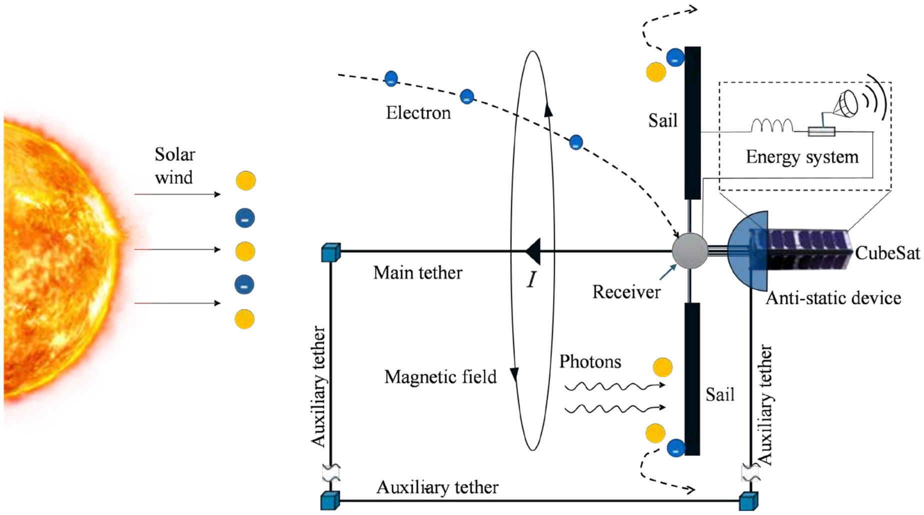
Fellow

Dr. Wen

Dr. John Z. Wen is a Professor in the Department of Mechanical and Mechatronics Engineering at the University of Waterloo, and the Columbiad Space Research Chair for In-Situ Resource Utilization & Stewardship. John is an internationally known researcher in the areas of fabrication and characterization of nanoenergetics, soot formation and combustion-synthesized carbon and metallic nanostructures and their applications in many fields.

John has trained more than 60 highly qualified research personnel in renewable energy system design, nanomaterial synthesis and characterization, electrochemical reactor operation and optimization, combustion theory and numerical modeling. He has developed technologies on novel methods and devices for the fabrication of nano-energetic composites and additive manufacturing of metal fuels for space propulsion.

A registered professional engineer in Ontario, Dr. Wen is an associate editor to two scientific journals and serves as Chair of CSME's Technical Committee on Microtechnology and Nanotechnology.



Lassonde Students Win Gold Medal for Novel In-Space Energy Harvest Concept

Demonstrating creativity, innovation, and a commitment to making a difference, a talented team from York University's Lassonde School of Engineering achieved a top position at the 2024 China International College Students' Innovation Competition. Competing against thousands of teams worldwide, the PhD candidates from Professor George Zhu's lab clinched third place in the international category and earned a prestigious gold medal for their groundbreaking project on in-space power generation technology, known as Dyson-Harrop CubeSat.

The competition involved two stages: a business proposal and a proof-of-concept presentation. The Lassonde team, consisting of Earth & Space Science PhD candidates Qi Zhang and Mitra Taghizadeh, along with Mechanical Engineering PhD candidates Hadi Jahanshahi, Fuzhen Yao, and Zhengze Liu, showcased their conceptual Dyson-Harrop CubeSat, which involves four CubeSats in formation connected by space tether. This system was engineered to capture energy from protons and electrons in solar wind based on the photoelectric effect, which has the potential to achieve significantly higher efficiency than current photovoltaic technology. Their innovative design effectively addressed key engineering obstacles in space conditions and transformed the Dyson-Harrop CubeSat concept from scientific fiction into a feasible engineering solution. The team estimated that the energy generated by a single Dyson-Harrop CubeSat could provide electricity for over 100,000 households or 20,000 space stations. The project was applauded for its ambitious effort to convert a science fiction concept into a viable engineering solution. The detailed design has been published on the top-tier journal in the field – Chinese Journal of Aeronautics (doi.org/10.1016/j.cja.2025.103510).

The team also developed an innovative technique for the precise, real-time management of the tether's dynamics, surpassing the constraints of traditional models. This approach is intended to enhance the efficiency of future space missions and create a pathway for sustainable energy capture, both in space and on Earth. — *Technical Editor, Dr. Ali Hosseini, MCSME*

Reference article:
https://lassonde.yorku.ca/reaching-for-the-stars-lassonde-students-win-gold-medal-for-space-tether-technology-concept

CSME STUDENT AFFAIRS REPORT

THE 2024/25 YEAR WAS ONE OF THE MOST active that we've seen in recent years. The University of British Columbia and Waterloo formed Local CSME Student Chapters, taking us to five total active chapters (besides University of Toronto, University of Alberta, and Western University).

The University of Alberta Local Chapter held an in-person Industry Mixer on March 7, 2025, where 11 industry representatives from companies such as Wyvern Space, General Motors, and Shell met with students to discuss their career paths and experiences.

A unique initiative led by the University of Toronto, University of Alberta, and Western University saw our first national-level online graduate school panel session. Representative faculty from each institution served as panelists to discuss what a future in graduate studies could look like and the career paths that may result through graduate training. The event was very engaging between faculty and students with excellent topics being discussed, and there is certainly appetite to consider having another in the future.

The major development for this year's National Design Competition (NDC) was the introduction of an "open format" for submissions. Other than a single-page, Executive Summary groups could submit their entries in their chosen format. The driving factor for this decision was to increase participation in the NDC by minimizing the amount of work required from students. We are exceptionally happy with interest in the NDC this year, receiving over 40 submissions. We are hopeful this trend will continue into the future years of the NDC as interest grows.

— Dr. Dan Romanyk, MCSME

PHOTO: UofA CSME LOCAL STUDENT CHAPTER INDUSTRY MIXER

History Committee: Archival Project

The History Committee is launching an initiative to document and archive basic historical information regarding Mechanical Engineering departments in universities and technical colleges across Canada.

While many of Canada's universities date back 100 years or more, the foundation of departments in the engineering disciplines is more recent. Many newer technical universities date from the 1960s, 70s, or later. Taking a brief voyage amongst the web pages of the various departments reveals a wide range of recorded history and facts.

We must recognize that word-of-mouth history is measured in spans of academic careers (20-30 years) and once our emeriti faculty pass away, we lose this memory. Hence, the urgency for some departments that are one to two generations old that have few records. Apart from basic facts (size, composition, evolution, when founded, who have been the leadership figures), contextual information (e.g. Why was your department founded and in what educational/societal context?), are also of interest.

The History Committee is also supporting the **Engineering Institute of Canada** initiative to archive interviews with diverse members of the engineering community, with the intention to make accessible interesting interviews and vignettes that may attract younger people into the profession. Although laudable, the rate of interviewing is understandably slow – considering the number of engineering associations in Canada. We are exploring the possibility of our own archival project, focused more at interviews with emeriti and retired members who simply have a good tale to tell! Inevitably, this requires resources: human and financial!

Members who wish to join and contribute to the History Committee are invited to email the Chair, Professor Ian Frigaard: frigaard@mail.ubc.ca

WELCOME NEW CSME/SCGM MEMBERS

October 1, 2024 to April 30, 2025

Mr. Luc Amar
Mr. Jeffrey Attala, *Ford Motor Company*
Mr. Isaac Baldwin, *Collins Aerospace*
Prof. Michael Benoit, *University of Waterloo*
Prof. Sampada Bodkhe, *Polytechnique Montréal*
Mr. David Brown, *Ansys*
Prof. Myriam Brochu, *Polytechnique Montréal*
Prof. Ahmad Al-Dabbagh, *University of British Columbia*
Mr. Esivue Eshilama, *Gastops*
Prof. Giovanni Ferrari, *École de Technologie Supérieure*
Mr. Maxime Gauthier, *Andritz Hydro Canada*
Prof. Didier Haillot , *École de Technologie Supérieure*
Prof. Matthew Harker, *École de Technologie Supérieure*
Prof. Marie Hébert, *Université du Québec à Trois-Rivières*
Prof. Arman Hemmati, *University of Alberta*
Mr. Adrian Ilinca, *École de Technologie Supérieure*
Ms. Lilian Kangethe
Mr. Khashayar Feizbakhshian Kohan, *Andritz Hydro Canada*
Mr. Mauricio Lombana, *Omniservices Engineering*
Prof. David Mélançon, *Polytechnique Montréal*
Mr. Sirshendu Misra, *University of Waterloo*
Mr. Yaseen Moftah
Prof. Giovanniantonio Natale, *University of Calgary*
Prof. Jovan Nedic, *McGill University*
Prof. Guyh Dituba Ngoma, *Université du Québec en Abitibi-Témiscamingue*
Prof. David St-Onge, *École de Technologie Supérieure*
Ms. Wing Yi Pao, *Ontario Tech University*
Mr. Payman Raphe, *The Master Group*
Prof. Hanie Rezaei, *University of Toronto*
Mr. Suhair Sabir, B*radken Canada Manufactured Products Ltd.*
Prof. Marlene Sanjose, *École de Technologie Supérieure*
Prof. Ojas Satbhai, *Pandit Deendayal Energy University*
Prof. Andy Simoneau, *University of New Brunswick*
Dr Liangzhu Wang, *Concordia University*
Mr. Zhengyuan Wang, *CPC Pumps*
Prof. Guangming Wang, *Shandong Agricultural University*
Prof. Malcolm (Mengqiu) Xing, *University of Manitoba*
Mr. Yumeng Yao, *Concordia University*
Prof. Junfeng Zhang, *Laurentian University*
Prof. Kun Zhang, *École de Technologie Supérieure*
Prof. Wen Zhong, *University of Manitoba*

TECHNICAL COMMITTEE REPORTS

Advanced Energy Systems

- Our TC promoted the ***Symposium on Advanced Energy Systems*** at the CSME Congress 2025 and supported the submission review process. We will continue to work with the organization committee and support the symposium within the Congress.
- We also planned several interdisciplinary webinars on various aspects on energy systems featuring both international and national invited speakers. These webinars will promote knowledge dissemination and collaborations.

– Dr. XiaoYu Wu, MCSME

Computational Mechanics

- The interests of this Committee include the development of new algorithms and non-standard applications of existing algorithms. Routine use of software packages for various simulations falls outside its interests.
- The Committee has completed its website.
- The Committee participates in the activities of the International Association for Computational Mechanics. The distribution of individual memberships among its members is being completed.
- The Committee is organizing a ***Symposium on Computational Mechanics*** as a part of the 2025 CSME Congress. This Symposium is sponsored by the Canadian National Committee for Mechanics (IUTAM).
- The Committee participates in the activities of the Canadian National Committee for Mechanics.

– Dr. J.M. Floryan, FCSME

Engineering Analysis and Design

- The TC Chair, Vice Chair and members are in place.
- TC Chair Aman Usmani and Vice Chair Hamid Akbarzadeh held a meeting with Hossain Rohani, Chair of the CSME TCs to discuss and plan for the TC activities such as topical seminars, webinars and symposia that can be used towards meeting the PEO (professional development requirements).

Activities in 2024-25

Two seminars sponsored by the TC were organized and delivered:

- “An Approach to Addressing vibrations in Vertical Cooling Water Pumps” by Aman Usmani (29 November 2024).
- "Artificial Intelligence (AI), Application in Nuclear Industry" and "Workshop on Large Language Models" by Dr. Moe Fadaee and Mr. Robin Manchanda of Kinectrics Inc. (25 March 2025).
- More webinars and seminars are being planned.

– Dr. Aman Usmani, FCSME

Manufacturing

Current activities:

1. Serving as an associate editor for the *Transactions of the Canadian Society for Mechanical Engineering*.
2. Organizing the ***Advanced Manufacturing Symposium*** at the 2025 CSME Congress at ÉTS.

Future activities:

1. Continuing to serve as an associate editor for *TCSME*.
2. Continuing the CSME webinar series on Manufacturing, featuring both international and national invited speakers.

– Dr. Farbod Khameneifar, MCSME

Materials Technology

TC Chair Zengtao Chen and Co-Chair Bill Atenhof have worked together with Elmira Moosavi of ÉTS to organize the ***Symposium on Materials Technology*** as part of the upcoming CSME Congress 2025. So far, we have 29 accepted papers and abstracts to be presented and two keynotes confirmed for the symposium.

Activities Planned for 2025

- Host the MT symposium at CSME International Congress
- Attend CSME board meeting and TCSME editorial board meeting during CSME International Congress.

– Dr. Zengtao Chen, FCSME

Mechatronics, Robotics and Controls

TC Activities:

- Recruiting active members from different universities and regions; significantly increased the number of TC Members and set up the contact list (done); invite one faculty member to be the TC representative at each university (plan to complete this by September 2025).
- Updating the website (done and ongoing).
- Organize the ***Symposium on Mechatronics, Robotics and Controls*** that will be held during CSME Congress 2025.
- Ad-hoc Panel Discussions on Topics of Interest (on going).
- There will be several seminars planned in the summer of 2025.
- MRC Three-Minute Contest: Plan to organize this in 2025; graduate students in the field of mechatronics, robotics and controls are welcome to participate.
- MRC Best Paper Award: Plan to organize this in 2025; graduate students in the field of mechatronics, robotics and controls are welcome to participate in the contest.

CSME Congress Activities:

- In the process of organizing symposia on Mechatronics, Robotics, and Controls in 2025.

Other Activities:

- Sketching the domain of Mechatronics technical areas, academic scope, and relevant industries in Canada (in process).

– Dr. Yang Shi, FCSME and
Dr. Homayoun Najjaran, FCSME

Solid Mechanics

- Prof. Akbarzadeh serves as ***Solid Mechanics Symposium*** Chair at CSME-CFDSC-CSR 2025 International Congress. To date, the symposium has received around 45 submissions and has secured a keynote speaker for the symposium.
- Prof. Akbarzadeh has reviewed submissions for the ***Solid Mechanics Symposium***.
- Prof. Akbarzadeh has been serving as an associate editor for the *Transactions of the Canadian Society for Mechanical Engineering* (papers submitted on topics related to solid mechanics and manufacturing).

— Dr. Hamid Akbarzadeh, FCSME

Transportation Systems

- CSME 2025 Congress: TC Chair, Dr. Yuping He and TC Vice Chair Dr. Bruce Minaker will co-chair the ***Symposium of Transportation Systems*** at 2025 CSME Congress.
- Reviewed seven papers submitted to this symposium.
- TC Chair will be a guest editor of the CSME *Bulletin* (Fall 2025).
- TC Chair serves as an associate editor of *Transactions of the Canadian Society for Mechanical Engineering*.

— Dr. Yuping He, FCSME

Cette année, nous sommes fiers de souligner les récipiendaires de nos prix : M. Jerzy Maciej Floryan, PhD (Prix Clifford N. Downing), M. Dominic Groulx, PhD (Médaille Jules Stachiewicz), Mme Cuiying Jian, PhD (Prix I.W. Smith), M. Mohsen Akbari, PhD (Médaille des technologies émergentes) et Mme Ya-Jun Pan (Médaille en mécatronique). Nous félicitons également nos nouveaux Fellows de la SCGM: M. Martin Agelin-Chaab, PhD, M. Hamid Akbarzadeh, PhD, M. Tobin Filleter, PhD et le M.John Wen, PhD.

Je tiens à remercier sincèrement notre directeur général, M. Guy Gosselin, pour son leadership et son soutien constants. Sous sa direction, le système d'adhésion a été mis à jour afin de faciliter l'accès aux reçus et aux avantages pour les membres, et nous préparons une mise à jour majeure du site web de la SCGM pour mieux servir notre communauté. Je remercie également M. Marc Secanell Gallart, PhD (Université de l'Alberta) pour son excellent travail en tant que rédacteur en chef du Bulletin de la SCGM, et souhaite la bienvenue à M. Ali Hosseini, PhD (Université Ontario Tech), qui assumera ce rôle important.

J'ai hâte de vous retrouver nombreux à Montréal pour le Congrès 2025 de la SCGM. Restons engagés et continuons à renforcer ensemble notre communauté.

La SCGM vit grâce à vous, vous sert, et vous représente véritablement.

Cordialement,

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Dr. You, Engineering Solutions for Bone Health (p. 12)

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Especially with AI and Generative AI in wearables, academic research often develops state-of-the-art algorithms, while industry facilitates collecting the necessary data, computing power, and infrastructure for refinement and deployment. These partnerships are crucial for successful and meaningful innovation.

Q: What do you think the future holds in your R&D area?

I see an incredibly promising future for R&D in wearable technology and biomechanics. It feels like we're right at the intersection of rapidly advancing sensor technology, computational power (especially AI and Generative AI), and better system integration. I expect continued progress in making sensors even smaller, more power-efficient, and able to capture a wider variety of biomarkers. This will give us much richer, more complete insights into someone's health.

AI will become more central, moving toward providing predictions and even suggesting actions. I expect AI algorithms will get significantly better at identifying early signs of health issues, predicting things like increased risk of fall or adverse cardiovascular events with greater accuracy. The use of Generative AI is also expanding such as creating personalized health advice, generating synthetic physiological data to help train AI models, and also simulating outcomes of different interventions to help with decision-making.

Also, integration will be another key domain. I believe wearable data will likely be integrated more seamlessly into broader digital health systems, like EHRs and telehealth platforms to translate insights into practice. There are of course many challenges such as data privacy, algorithmic bias, and regulations, but I believe the trend points towards wearables becoming a fundamental part of future healthcare. The ultimate goal is wearables to become continuous, personalized, and preventative.

CALL FOR SUBMISSIONS:

ADVANCES IN AEROSPACE

As the Editor of the Canadian Society for Mechanical Engineering (CSME) *Bulletin*, I would like to invite you to submit any of the following items for consideration for publication in the next CSME *Bulletin* issue. For examples of prior contributions, please see previous issues at www.csme-scgm.ca/bulletin.

The next issue focuses on *Advances in Aerospace* and will be published in November 2025. The guest editors of the issue will be Professors Dana Grecov, chair of the Fluid Mechanics Engineering Technical Committee (TC) and Yuping He, chair of the Transportation Systems TC. We are looking for contributions in the following areas:

FEATURED ARTICLES

The aim of the featured articles is to give our readers an overview of a given sub-topic of the theme (*Advances in Aerospace*), the most recent advancements in the area, and finally, the most critical aspects for future research. The article should be 1,200 words (9,000 characters including spaces) long. If you are interested in submitting a featured article, please submit an Expression of Interest (EoI) by sending a 300-word abstract of the article and a 50-word biography to either SayyedAli.Hosseini@ontariotechu.ca or rwilling@uwo.ca by July 1, 2025. The most significant contributions will be invited to submit a full featured article that will be due on Oct. 1, 2025.

SHORT NEWS ITEMS

News of interest to the ME community prior to Oct. 1, 2025.

RECOGNITIONS

Highlighting the achievements of ME peers *(not self)* prior to Oct. 1, 2025.

IN MEMORIALS

Recognizing the passing of ME members prior to Oct. 1, 2025.

FACULTY SPOTLIGHT

This section highlights new faculty in the Mechanical Engineering Departments across Canada within four years of their appointment, ideally working on the topic of the issue (though not essential). The aim of this section is to introduce new faculty members to the CSME community; therefore, the article should provide a short biography, an introduction to your research (what is the topic of your research? why is the research topic important?) and a description of your laboratory including past and future work. If you are eligible and interested in submitting an article, please submit an Expression of Interest (EoI) by sending a 100-word abstract and a 50-word biography to either SayyedAli.Hosseini@ontariotechu.ca or rwilling@uwo.ca by July 1, 2025. The most significant contributions will be invited to submit a full article (500 words or 4,000 characters) that will be due on Oct. 1, 2025.

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

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Dr. Li, Population Diversity in Knee Joint Contact Mechanics (p. 8)

the most prevalent knee geometry variations in the population and thus require fewer finite element analyses than subject-specific modelling. A specific mode variation is highlighted in shape modelling and the related changes in mechanics may be more conveniently identified, which would be otherwise hidden in mixed results from a large number of subject-specific analyses on every individual. It is worthwhile noting that it would be time-consuming to include all principal components for finite element analyses. Another challenge is to identify the exact shape variation among the principal modes, which makes it difficult to interpret the results. For example, PC1 primarily characterized size changes, but also included a secondary shape change. An advanced algorithm may be developed to determine the geometric differences among different principal modes.

We started shape modelling using 31 knees from Caucasian males, which may not be sufficiently powered to represent variability within the cohort. We are currently doubling the size of this cohort to determine the right size of the dataset for characterizing a subpopulation before investigating the effect of sexes and races on joint contact mechanics and fluid pressurization. The current modelling process still requires large amount of finite element simulations. Studies on several subpopulations may be accelerated by introducing machine learning to improve the computational framework, after having gained experience and new insights into population modelling.

The ultimate goal of this research is to determine the intra- and inter-variations in knee joint contact mechanics and fluid pressurization for different subpopulations accounting for sex, race and age differences. A framework has been established for this purpose, and preliminary results thus far obtained indicate the need for this type of modelling, although a bigger picture of population diversity in knee joint mechanics is yet to be determined. New knowledge gained from this research may serve osteoarthritis modelling, joint injury prevention and repair.

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Dr. Landry, Wearable Cardiovascular Health Technologies (p. 17)

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The CSME would like to acknowledge the support from the following ME Departments

La SCGM tient à remercier les départements de génie mécanique suivants pour leur aide

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