# Colloque Annuel

CREPEC

Centre de recherche
sur les systèmes polymères et
composites à haute performance

VENDREDI 4 DÉCEMBRE 2026
9H À 18H




UNIVERSITÉ CONCORDIA
JOHN MOLSON BUILDING
CENTRE DES CONFÉRENCES

| Déroulement | | |
|---|---|---|
| 8h30 | Arrivée des participants | |
| 8h50 | Mot de bienvenue | |
| 9h00 | Prof. Navid Zobeiry<br>U.Washington | Physics-Guided AI for Polymer Composites: From Formulation to Manufacturing and Performance |
| 10h00 | Pause-café | |
| 10h30 | Panel – Impact de l'IA sur la conception des matériaux polymères et composites | |
| 12h00 | Dîner | |
| 13h15 | Réunion des membres & Comité de la Relève | |
| 13h45 | Discussion - Axes de recherche CREPEC | |
| 14h30 | Loïc de Bluze<br>u.Laval | Évaluation du vieillissement hygrothermique des réparations composites wet lay-up par une approche de température équivalente |
| 14h45 | Pause-café | |
| 15h15 | Prof. Bruno Blais<br>Polytechnique Montréal | AI for chemical and manufacturing processes: from black boxes to process control |
| 15h30 | Prof. Frédérick Gosselin<br>Polytechnique Montréal | FENNM: A Hybrid Finite Element–Neural Network Method Applied to Composite Cure Simulation and Polymer Property Identification from Digital Image Correlation |
| 15h45 | Prof. Sasan Karganroudi<br>UQTR | Geometric AI for Intelligent 3D Inspection of Non-Rigid Industrial Components: Perspectives for Composite and Polymer Structures |
| 16h00 | Session Étudiantes | |
| 17h00 | Réseautage | |

# Physics-Guided AI for Polymer Composites: From Formulation to Manufacturing and Performance



**Prof. Navid Zobeiry**
University of Washington
Seattle, Washington, USA

Developing high-performance polymer composites requires decisions spanning material formulation, characterization, manufacturing, and structural design. These decisions are closely coupled: material chemistry influences processing behavior, manufacturing conditions affect material properties and variability, and the resulting material state determines structural performance. Conventional approaches rely on extensive experimental characterization and computational modeling, making systematic exploration and optimization challenging. Integrating AI/ML with physical models and experimental evidence offers opportunities to accelerate these workflows and connect different stages of composites development. This talk presents interconnected research efforts that use physics-guided AI to advance composite materials engineering. Examples include chemistry-informed formulation optimization, physics-guided surrogate models for material characterization and targeted testing, and multi-fidelity approaches for accelerated model calibration, process simulation, and design exploration. Bayesian inference and uncertainty quantification provide a framework for understanding how variability in materials and manufacturing processes influences structural performance. An integrated multiscale process–failure modeling framework illustrates how these approaches can support predictive assessment of composite strength distributions and model-assisted qualification. Looking ahead, the talk will introduce emerging opportunities in JAX-based differentiable physics simulation for coupled optimization of material, process, and geometric variables.

# Panel – L’intégration de l’IA sur la conception et la fabrication des matériaux polymères et composites

À venir

# Évaluation du vieillissement hygrothermique des réparations composites wet lay-up par une approche de température équivalente



**Loïc de Bluze**
Candidat au Ph.D.
Université Laval, Québec, Canada

Les matériaux composites occupent une place croissante dans l'industrie aérospatiale, et leur réparation devient souvent la seule option lorsque le remplacement d'une pièce est impossible ou trop coûteux. Les réparations collées sont privilégiées, mais la majorité des travaux portent sur des matériaux préimprégnés, qui exigent un stockage au congélateur et souvent une cuisson en autoclave. Ces contraintes logistiques limitent leur utilisation en maintenance. Les réparations collées réalisées par stratification au contact (wet lay-up) constituent une alternative simple, ne nécessitant que peu d'équipement spécialisé. Leur performance demeure toutefois peu documentée, en particulier en environnement chaud et humide, reconnu comme un facteur déterminant de dégradation des propriétés mécaniques.

Cette présentation porte d'abord sur la caractérisation mécanique des matériaux de réparation wet lay-up (traction, Iosipescu, Short Beam Shear) couplée à la corrélation d'images numériques, ainsi que sur la dégradation de leurs propriétés sous l'effet combiné de la température et de l'humidité. Une température élevée équivalente, permettant de reproduire l'effet de l'humidité absorbée tout en évitant les longues périodes de conditionnement, est ensuite identifiée. Cette approche est ensuite appliquée à des réparations collées en escalier afin d'évaluer sa capacité à reproduire la perte de performance associée au vieillissement hygrothermique. Enfin, l'influence de différents paramètres de conception tels que le système de résine, la longueur des marches et l'ajout de surplis est examinée.

# AI for chemical and manufacturing processes: from black boxes to process control



**Prof. Bruno Blais**
Polytechnique Montréal
Québec, Canada

From the design of mixing tanks to the cooling of injection molds, artificial intelligence (AI) is rapidly finding its way into chemical and manufacturing processes. Neural networks can learn complex non-linear relationships between operating conditions and process performance, and they can be evaluated in a fraction of the time required by experiments or simulations. This comes with two caveats. First, data-driven models are only as good as their training data, and generating high-quality data for chemical processes remains expensive. Second, AI is not a single tool: how it should be used depends on how much data is available, how much of the physics is known, and what the model will ultimately be used for. We strongly believe that the key to AI-driven process engineering lies in combining these models with high-fidelity simulations, physical knowledge and automated experiments.

In this talk, I will discuss four ways in which our group has used AI for chemical and manufacturing processes: As a pure black box, as a physics-informed neural network (PINN), coupled with robotics and as a tool for process control.

Using these examples, we will discuss lessons learned on data generation, sampling strategies and the role of physical constraints when data are scarce. We conclude by reflecting on the role of open-source simulation tools, such as our CFD software Lethe, in generating the data that fuels these models. Finally, we outline future directions, including the integration of AI surrogates in model-based control of manufacturing processes.

# FENNM: A Hybrid Finite Element–Neural Network Method Applied to Composite Cure Simulation and Polymer Property Identification from Digital Image Correlation



**Prof. Frédérick P. Gosselin**
Polytechnique Montréal
Québec, Canada

Many challenges in the processing and characterization of polymers and composites can be cast as coupled forward and inverse problems: predicting the thermochemical history of a laminate during cure, or identifying the constitutive properties of a material from full-field measurements. Physics-Informed Neural Networks (PINNs) offer an attractive framework to combine experimental data with governing equations, but they are sensitive to initialization and typically require problem-specific tricks to converge on stiff, strongly coupled systems. For composite cure, for instance, a successful PINN solution required tailored output activation functions, adaptive loss weighting, and sequential training of decoupled networks.

We present the Finite Element Neural Network Method (FENNM), a hybrid solver that combines the flexibility of deep learning with the rigorous formalism of the finite element method. Formulated within a Petrov–Galerkin framework, FENNM uses a neural network to generate the global nonlinear space of trial solutions, while the test functions are taken from the non-vanishing Lagrange shape function space. By retaining the flux terms at element boundaries, natural boundary conditions, interface fluxes and point loads are embedded in a single weak-form residual loss, which significantly improves training stability.

Two applications are discussed. First, FENNM is applied to the two-way coupled thermochemical cure benchmark of Amini Niaki et al.: an AS4/8552 laminate on an Invar tool subjected to a 222-minute autoclave cycle, where transient conduction across a 20-fold conductivity contrast is coupled to stiff, autocatalytic cure kinetics. Using a Dirichlet–Neumann domain-decomposition, space–time formulation marched over sequential time slabs, standard multilayer perceptrons are trained on a single coupled variational functional, without problem-specific activations, loss-weight tuning or staggered training. FENNM reproduces the temperature history over the full cycle with a global relative L2 error of 0.80 % and captures the internal exotherm overshoot (≈ 220 °C), as verified against an independent finite element solver. Second, FENNM is used to solve inverse problems with Digital Image Correlation data, identifying the Young's modulus and Poisson's ratio of PMMA from open experimental datasets in uniaxial tension and three-point bending ; the extension of this approach to nonlinear constitutive laws is also discussed. These cases show how FENNM offers a more general, less tuning-dependent path toward digital twins of polymer and composite manufacturing and testing.

# Geometric AI for Intelligent 3D Inspection of Non-Rigid Industrial Components: Perspectives for Composite and Polymer Structures



**Prof. Sasan S. Karganroudi**
Université du Québec à Trois-Rivières (UQTR)
Montréal, Canada

Lightweight and flexible components made of composite and polymer materials are widely used in automotive, aerospace, and wind energy applications, including vehicle body panels and fenders, aircraft fuselage and cockpit panels, and wind turbine blades. Their geometric quality control and in-service inspection present significant challenges due to their non-rigid behavior, complex geometries, and susceptibility to deformation during handling and measurement. In particular, distinguishing reversible deformations from actual geometric anomalies remains a major challenge for conventional 3D inspection approaches. This presentation explores the potential of geometric machine learning and deep learning methods for intelligent, fixtureless 3D screening of non-rigid industrial components. By processing 3D point clouds acquired through laser/optical scanning, these approaches can learn geometric characteristics, identify potentially defective components, and localize suspicious regions without necessarily requiring complex physical fixtures or computationally intensive non-rigid registration.

Building on recent research in geometric deep learning for flexible industrial parts, the presentation discusses how AI-assisted geometric screening can complement conventional dimensional metrology and non-destructive inspection. Rather than replacing comprehensive defect detection and dimensional verification, the proposed approach aims to rapidly identify geometric anomalies and prioritize components or regions requiring further inspection. Particular attention is given to the opportunities and challenges of extending these approaches to composite and polymer structures, where material behavior and deformation characteristics must be considered. The proposed perspective highlights the potential of geometric AI to support more efficient, automated, and scalable quality control and maintenance strategies for next-generation lightweight industrial structures.

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CREPEC est un regroupement scientifique financé par le FRQ-NT.

Fonds de recherche Québec