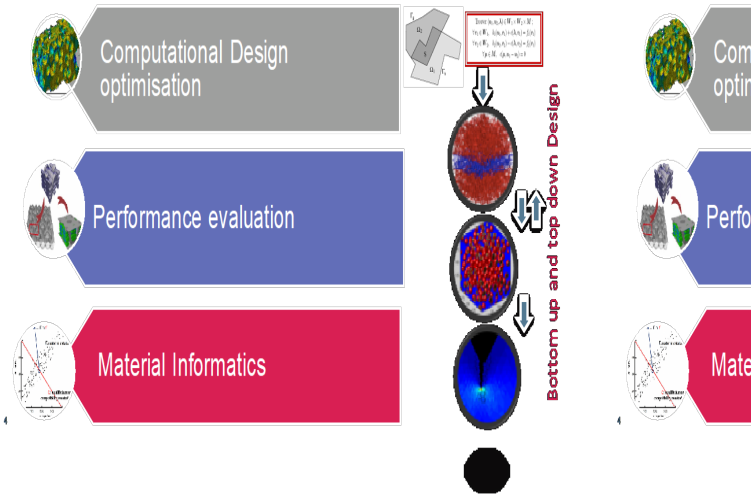
RESEARCH GROUP

www.list.lu/en/materials/structural-composites/group/?tx_listreference_pi1%5BresearchGroup%5D=176&cHash=2b4cdeec9c9a42b47d4017042f699723

Composite Modelling



Combining computational mathematics, computer science and composite materials science and engineering, our research work is characterized by a horizontal diversification of highly competent scientific staff complementing a vertical diversification of a service portfolio across the entire product development chain and materials research disciplines. Accordingly, our research group possesses the necessary knowledge and wealth of experience, needed to:

- Develop a physically meaningful composite material design thanks to the integration of advanced materials modelling coupled with uncertainty management and reliability analysis,
- Accelerate development, adoption and use of new composite materials and
- Increase the fraction of critical design and decisions informed by modelling and simulation.

Main expertise fields

1. Computational Design optimization
    - Microstructure reconstruction, generation, analysis and optimization
    - Functional Design: right-the-first time thanks to end-to-end modelling and simulation workflows with increased accuracy and interoperability

- Performance evaluation and interoperability
    - Predictive multiscale material relations that bridge microstructures with the continuum concurrently via statistical averaging and monitoring the microstructure/defect evolutions (i.e., manufacturing processes)
    - Materials-Process Relationships to truly close the loop between as-designed and as-manufactured composites material, products and structures

- Material Informatics (MI)
    - MI for material microstructure analysis: Use data-centric approaches and leveraging machine learning technology for composite materials design and manufacturing
    - MI for material selection/design: Inductive methodologies and tools for microstructure-property correlations
    - MI to accelerate composite material design: Innovative approaches to accelerate the "forward" direction of innovation (properties are realized for an input material) and to enable the "inverse" direction (materials are designed with desired properties)

Research challenges

The core of our research philosophy and methodology is to seek and drive collaborations and research with the goal of:

- Effectively linking computations and experiments (data-driven computational modelling) to tailor functional composite materials,
- To develop the systemic understanding of the entire product development chain of composite components to be digitized and to bundle the methodological and scientific experience and capabilities required for this purpose.

Given its complexity, this goal can only be successfully realized if simultaneously specialized robust solution techniques, high-performance algorithms and software tools for highly advanced computing facilities, including those based on parallel and distributed processing, are developed and deployed for this purpose. Our current and emerging challenges can be summarized as follows:

Challenge 1: Description and Evolution of Microstructures of Composite Materials

- Design and optimization of microstructures using consistent tools for microstructure-property relationships, incorporating experimental characterization techniques and manufacturing processes
- Development of a reliable digital material twin that realistically describes the physical scale relationship between the microstructure and the composite performance

Challenge 2: Scale-Coupled and Data-Driven Material Modelling

- Multiscale modelling to link top-down and bottom-up different length scales and physics
- Data-driven modelling to directly describe the effective material response at the component level, reducing the complexity and computational cost of multiscale methods

Challenge 3: Digitally Supported Product Development Process

- Interoperable linking of computer-aided processes with the goal of an end-to-end designable product development process
- Simulation of manufacturing processes of multiscale composite components and integrating them into the computer-aided concept phase and simulative material development

Challenge 4: Multidisciplinary Design Optimization and Decision Making

- Multicriteria design optimization of composite components across all phases of product development, taking uncertainties, risks, and opportunities into account
- Simultaneous optimization of composite microstructures with the effective use of material models at the different scales

Application areas

- Microstructure (Re-)Construction, Multiscale Modelling and Analysis
- Functional Composite Structures Modelling, Design and Analysis
- Material parameter identification and simulative test validation
- Material and Process Modelling empowered Decision Making
- Reliable Digital Twin Microstructure and RVE Generation
- Manufacturing Process Modelling and Design

Main assets

- Internationally leading and talented researchers with proven track record offering the knowledge in mathematical modelling, optimization techniques, numerical methods, high-performance and parallel algorithms and large-scale scientific computation.
- Long-term collaborations with world-leading companies and research groups.
- Wide range of In-house software capabilities.
- Proficient use of scientific software tools and programming languages: Abaqus, COMSOL, MATLAB, Simulink, Scilab, Fortran, C/C++ and Python.

Selected publications

- Efficient uncertainty quantification and management in the early stage design of composite applications.
- Data-driven multiscale finite element method: From concurrence to separation.
- Transverse compaction of 2D glass woven fabrics based on material twins: Part 1 and Part 2.
- A data-driven analysis on bridging techniques for heterogeneous materials and structures.
- Identification of the material parameters of a viscous hyperelastic constitutive law from spherical indentation tests of rubber and validation by tensile tests.
- Global sensitivity analysis of solid oxide fuel cells with Bayesian sparse polynomial chaos expansions.
- A two-phase self-consistent model for the deformation and phase transformation behaviour of polymers above the glass transition temperature: application to PET.
- Effective conductivity in isotropic heterogeneous media using a strong-contrast statistical continuum theory.
- A micro–meso-model of intra-laminar fracture in fiber-reinforced composites based on a discontinuous Galerkin/cohesive zone method.
- An XFEM crack-tip enrichment for a crack terminating at a bi-material interface.
- An ABAQUS toolbox for multiscale finite element computation.
- X-FEM implementation of VAMUCH: Application to active structural fiber multi-functional composite materials.
- Static, free vibration and stability analysis of three-dimensional nano-beams by atomistic refined models accounting for surface free energy effect.
- Integration of material and process modelling in a business decision support system: Case of COMPOSELECTOR H2020 project.
- Optimal design of multi-step stamping tools based on response surface method.

Partners

Goodyear Technical Centre, e-Xstream Engineering, ArcelorMittal, Siemens-Samtech, Saint Gobain Research, Dow Europe, Airbus, ESI-Group, ESTECO, Alcuilux , Weber , ESA (European Space Agency) , Open Engineering, SIMEDA-Antogyr, IEE, Luxembourg, Euro-Composites, Tarkett, Saint-Gobain, Abrasives, Luxembourg, Rioatrex Puretec

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