EUROMECH Colloquium 559
"Multi-scale computational methods for bridging scales in materials and structures"
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Background

In recent years, considerable progress has been made in bridging the mechanics of materials to the structural engineering level supported by advances in multi-scale modelling. Different classes of computational scale bridging methods have been developed to this purpose, spanning different disciplines, e.g. engineering, computational mechanics, mathematics, physics, chemistry etc. Although these methods have usually been equipped for a specific research problem, from a methodological point of view, similarities and distinctive features can be identified. Examples include:

- Methods that either rely on the separation of scales principle, or directly embed the fine scale model in the course scale one, leading to either nested or concurrent solution procedures;
- Two-way coupling (fine-coarse and vice versa) or one-way (fine scale informed coarse scale model);
- The use of fine scale models for either extracting new emerging phenomena at the coarse scale, or quantification of the a-priori known coarse scale behaviour.

EUROMECH Colloquium 559 served as a forum for bringing together scientists from different disciplines working on scale bridging problems (both spatial as well as temporal) in materials and structures. The Colloquium aimed to identify common and distinct features of different techniques as well as their limitations and upcoming challenges, in order to stimulate interdisciplinary cross-fertilisation.

The colloquium attracted about 60 participants from various European countries, as well as The USA, Japan and Argentina. The scientific program included 33 invited oral presentations and 15 contributed posters. The presentations and posters covered a broad range of multi-scale subjects.

Colloquium Topics

The following topics were addressed throughout Colloquium 559.

- **Multi-scale modelling of damage and fracture.** Damage and fracture are by their nature multi-scale processes initiating at the very fine microscopic scale and propagating through scales up to the macroscopic cracking and failure. This is a particularly challenging topic, since fundamental hypotheses such as scale separation are violated in the case of damage and fracture. This requires the development of dedicated multi-scale schemes, several of which were presented and discussed during the Colloquium.
- **Model order reduction techniques in space and time** Many scale bridging techniques, especially those suitable for non-linear problems, lead to high computational costs. This hampers their application to the practical problems relevant for engineering practice. Dedicated multi-scale reduced-order modelling techniques are needed. Several such approaches were presented.
- **Uncertainty and stochasticity** The issues of randomness, uncertainty and stochasticity in geometrical and material properties are inherent to microstructures. In scale bridging, it is therefore important to consider the propagation of microstructural stochasticity towards the macroscopic material and structural performance. Multi-scale approaches dealing with these issues were discussed.
- **Coupled-field, multi-scale problems** The use of advanced materials requires solution of multi-scale, multi-field problems. Typically the mechanical stress field is coupled to other fields, such as diffusion of certain elements, phase transformation, electrical and magnetic fields and fluid-

saturated porous media. This requires the careful reconsideration of single-field multi-scale approaches and the development of new techniques.

- **Surface and interface phenomena** Consideration of multi-scale phenomena at the surfaces and interfaces brings in new challenges, These were illustrated by multi-scale modelling of friction, delamination of polymer-metal interfaces and coarse-grained atomistics with free surfaces.
- **Expanding application areas** Application areas requiring multi-scale and scale bridging methods for materials and structures is growing. It spans classical engineering materials, such as metals, polymers and composites, through natural materials that include geological and granular materials, to materials that enable new emerging technologies.

The Colloquium programme included a visit to the Multi-scale Laboratory of the Mechanics of Materials Group at Eindhoven University of Technology, where new experimental techniques for multi-scale material characterisation were demonstrated. We thank our sponsors: 3TU Research Centre "Fluid and Solid Mechanics’, Eindhoven Multiscale Institute and Université Paris-Est Marne-la-Vallée. Finally, we thank EUROMECH for making this meeting possible, and for financial and organisational support.