EUROMECH Colloquium 584

"Multi-uncertainty and multi-scale methods and related applications"
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The development of multi-uncertainty and multi-scale models has received significant attention over the last decade. New mathematical formulations and numerical solution strategies allied to the increase in computational power/cost ratio have fostered a dramatic growth in this rapidly expanding field. Research activity in this area has been devoted to the development and combination of different analytic tools and computational methods for application in fields as diverse as metal processing, composite materials, oil & gas development, fuel cell technology and biomedical tissue engineering. Such developments have played a central role in the understanding of the interaction among multi-physics and multi-uncertainty phenomena taking place at multiple scales in space and time. Nevertheless, new challenges continue to emerge, driven mainly by advanced industrial applications. These outstanding challenges continue to drive leading edge research in computational mechanics and computational engineering.

It is also true that in many scientific and engineering problems, the challenges associated with multi-scale and multi-uncertainty often occur together and may be coupled. Therefore, a synthesised solution approach is required. EUROMECH Colloquium 584 targeted the latest advances in the modelling of multi-uncertainty in multi-scale problems. The main aims of the colloquium were:

1. To present the state-of-the-art in this field by showing the most recent developments by leading experts;
2. To provide a forum for discussion of current research trends and future challenges in computational multi-uncertainty and multi-scale modelling.

Colloquium 584 had 38 presentations and about 50 participants. Key-note lectures from seven invited speakers must be highlighted, given their valuable contributions to the success of the colloquium:

1. Marc Geers, Eindhoven University of Technology: "Modelling of interfaces in engineering materials across the scales";
1. Javier Oliver, Technical University of Catalonia (UPC/Barcelona Tech) and International Centre for Numerical Methods in Engineering (CIMNE), Barcelona, Spain: "Hyper-reduced order modelling (HPROM) in multiscale fracture";
2. Michael Beer, Institute for Risk and Reliability, Leibniz University Hannover, Germany; Institute for Risk and Uncertainty, University of Liverpool, United Kingdom; Shanghai Institute of Disaster Prevention and Relief, Tongji University, China: "Coherent models for aleatory and epistemic uncertainties";
3. Wing K. Liu, Northwestern University: "Modelling and simulation challenges in materials design for additive manufacturing applications";
4. Ron Bates, Rolls Royce plc: "Multiscale robust design for product development";
5. Manolis Papadrakakis, Institute of Structural Analysis & Antiseismic Research - National Technical University Athens, Greece: "High performance methods for non-intrusive and intrusive multiscale stochastic simulations";
6. Eduardo de Souza Neto, College of Engineering, Swansea University, UK: "The method of multiscale virtual power: a variational recipe for derivation of RVE-based multiscale models".

From the above presentations and the interesting discussions they generated, along with other authors´ presentations, it was possible to develop stimulating ideas with the following highlights.

1. Multi-scale modelling, based on computational homogenisation, sets a very demanding challenge. The multiplicative (through-scales) computational cost might make the multi-scale analysis unaffordable for real problems involving a large number of RVE re-evaluations, as in non-linear models and time-advancing analysis. For the forseeable future, intensive computing techniques seem inadequate to address the computational costs involved in these type of problems. Therefore, algorithmic speed-up techniques that reduce the computational cost of the RVE model by means of specifically devised algorithms appear as a suitable remedy.
2. Uncertainties in structural and system parameters and in environmental conditions and loads are challenging phenomena in engineering analyses. They require appropriate mathematical modelling and quantification to obtain realistic results when predicting the behaviour and reliability of engineering structures and systems. The modelling and quantification are complicated by the characteristics of the available information, which involve, for example, sparse data, poor measurements and subjective information. This raises the question whether the available information is sufficient for probabilistic modelling. The framework of imprecise probabilities provides a mathematical basis to deal with these problems, which involve both probabilistic and non-probabilistic characteristics of information. A common feature of the various concepts of imprecise probabilities is the consideration of an entire set of probabilistic models in one analysis.
3. The design and development of complex engineering products requires a structured Systems Engineering approach. This task can be broken down into the design of systems, sub-systems and components, all supported by detailed simulation models that validate the overall design against requirements. Evaluating these simulation models can be costly, and this cost can rise dramatically if the robustness of the system to uncertainty is to be assessed. There is great potential in reducing this cost by aligning these engineering models so that they are evaluated at an appropriate design scale and level of fidelity to address the question of component, sub-system and system validation as efficiently as possible.
4. One of the future trends identified is the development of new materials, which facilitate advancement of the world of design and manufacturing. Additive Manufacturing (AM) enables the printing of 3D complex geometries that are otherwise impossible to manufacture, such as a part within a part. AM comes in many different varieties for numerous material systems including polymeric, biological, cement-based, and metallic materials. These processes typically involve an accumulation of cyclic phase changes, such as melting and solidification of metallic particles, until the desired 3D geometry is achieved. This has major implications for concurrent material and product design, as it is possible using AM to adjust material composition for bulk property improvement or functional grading within the material. There is a strong need for robust and efficient modelling and computational approaches which improve predictive capabilities.

By providing a focused platform and a relaxing environment for face-to-face communications, the conference was well received by the participants and the wider research community. Valuable insights were developed through discussion panels and presentations. Participants with different backgrounds were keen to contribute their expertise. A special issue on “Multi-uncertainty and multi-scale methods and related applications”, jointly edited by the conference chairmen, will be published by Engineering Computations. Plans have already been made to meet again in 2017, with a view to a biannual international event. We thank EUROMECH for all the support in making Colloquium 584 possible.