Guest editorial

Computational methods in multi-scale, multi-uncertainty and multi-physics problems

Over the last decade, we have seen a growing demand for rigorous constitutive modelling and uncertainty quantification in conjunction with experiments to support decision-making in the design, development and deployment of novel materials and structures. Conventional modelling has focused on gaining insight into the range of mechanisms that control the behaviour and how those mechanisms govern the overall response. In that context, understanding the interaction among multi-physics and multi-uncertainty phenomena taking place at multiple scales in space and time was not a priority. As computational modelling of multi-uncertainty and multi-physics problems advances, there is increasing motivation to use it within the context of design and qualification. This trend is clear and is described in a recent NASA report, "Vision 2040: A Roadmap for Integrated, Multi-scale modelling and Simulation of Materials and Systems" (Liu *et al.*, 2018). Invariably, the need to embrace the challenge of multi-scale, multi-uncertainty and multi-physics modelling has arrived and has already received significant attention. New mathematical formulations and numerical solution strategies allied to the increase in computational power/cost ratio have fostered intense progress in this rapidly expanding field. It is now becoming possible to solve industrial multi-physics problems coupled with stochastic analysis through parallel computing techniques, which were unthinkable some years ago. Nevertheless, new challenges emerge from a theoretical and practical perspective that continue to drive the forefront of research in computational mechanics and engineering.

This special issue contains 19 selected papers. The majority of them were presented at the ECCOMAS thematic conference on Computational Modelling of Multi-Scale, Multi-Uncertainty, and Multi-Physics Problems held from 15 to 17 July 2019 in Porto, Portugal. We hope that the special issue provides an overview of some of the community's latest research works and highlights unique challenges, including approximate physics, scale separation violation, weak coupling, and uncertainty across scales. This diverse collection of articles aims to stimulate research in this wide area and serve as a valuable reference such that the treatment of multi-physics and multi-uncertainty at different scales becomes a routine aspect of modelling. The following topics are covered: enhanced machine learning for identifying unified single layer feed-forward neural networks models; hierarchical and zonal modelling for both turbulence and geometry; design and optimisation of fibre reinforced composite materials; Bayesian experimental design for CO_2 sequestration with leakage risk assessment; global sensitivity analysis for multiple failure modes based on convex-probability hybrid uncertainty; design of prismatic tensegrity cylinder subjected to a compressive force with fundamental parameters for a minimal mass; combination of computational fluid dynamics, the discrete element method and the population balance method to study the dynamic of agglomeration process; the use of analytical solutions of the linear theory of circular arches for engineering design; a response surface method based on the adaptive bivariate cut-high dimensional representation method; dynamical Shakedown analysis of high-rise tower structure; multi-scale optimization and design of woven composite cut-out structures; a forecast model based on support vector machine optimized by particle swarm optimization with compression factor for predicting the roll gap in acceleration and deceleration process; a three phase interpenetrating continua approach for wave and porous structure interaction; a two-stage homogenization for modelling of

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elastic-plastic functionally graded composites; the in-plane dynamic response of a hydraulic pipe subjected to random vibration; direct energy deposition metamodeling using a meshless method; development of multiscale multi-physics based modelling and simulations with the application to precision machining of aerofoil structures; atomic-scale simulation of Hugoniot relations and energy dissipation of polyurea under high-speed shock; and a scaling procedure for designing accidental gas release experiment.

We hope that the readers of this special issue will benefit from the range of techniques and applications presented and will gain a new appreciation of both the challenges and opportunities facing this critical field.

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Reference

Liu, X., Furrer, D., Kosters, J. and Holmes, J. (2018), Vision 2040: A Roadmap for Integrated, Multiscale Modeling and Simulation of Materials and Systems, NASA/CR-2018-219771 NASA Glenn Research Center.