Special Issue on Multi-physics Problems

Preface

Modelling the behavior of engineering structures needs a deep insight into the phenomenology of the particular physical processes, which ought to be taken into account. Simplified engineering models usually focus on the most important process, which describes the evolution of the design variable by means of often simplified and sometimes heuristic model equations. Moreover, the current majority of engineering models are usually limited to describing a single process in space and time. Hence, the extension of design requirements to include the coupling and interaction of the main process for design variable with additional variables and the corresponding processes is the currently main novelty in research in Mechanics. Within this modern framework of Coupled Systems Mechanics, we can develop for example, advanced models providing more reliable predictions on durability of structures. The essential novelty here pertains to interaction of different processes that may change the evolution of the primary design variables, or even the complete phenomenology of the behavior of the structure. More precisely, the interaction of different processes leads in general to an exchange of energy or substances, which can induce global instabilities of the structural behavior or trigger local processes such as phase transformations, erosion or bio-chemical degradation of matter.

The proper description of the interaction of different processes requires in general very advanced models referred to as “multi-physics“ or “multi-field“, which have to be developed or extended individually for each application. If the interaction of processes is governed by the exchange of energy or substances at the surface, a surface coupled model may be generated by a direct coupling of the single field formulations, which are connected to each other. This is the case, if a solid structure is in interaction with water or air (i.e., fluid-structure interaction). Modern approaches to solution of the multi-field equations use coupling of different solvers (e.g., for the fluid and for the structure) externally by means of an iterative algorithm enforcing the coupling conditions. A monolithic approach is necessary sometimes, if the structures happen to be very sensitive to perturbations, or in more general cases when severe nonlinearities can lead to instabilities of the coupled system as divergence, flutter or limit cycle oscillations.

The second type of coupled systems covers volume coupled processes, where structural deformations and damage are coupled with thermo-dynamical processes, chemical reactions and even biochemical degradation of matter. Some representative examples are the hydration of young concrete and dehydration of concrete at high temperature (e.g., see paper of Ostermann *et al*.), aging of concrete (e.g., see paper of Cramer *et al*.), thermo-plasticity of metals, or degradation of waste. Since these processes are strongly coupled at each material point, it is more subtle (e.g., see paper of Niekamp *et al*.) to separate them from the beginning and to couple them afterwards than the interacting and surface coupled systems. Furthermore, processes of this kind take place at different spatial and temporal scales. For example, soils settlement is usually a smooth process in space and time. On the other side, land slide dynamics is a sudden process, which is initiated once the limit state of strains or stresses is reached. Temperature is governed by heat transfer that is a smooth process in space and time, but can initiate a sudden local damage due to a decreasing resistance of material, which may further lead to global instabilities of structures (e.g., see paper of Ngo *et al*.). For modelling of these processes, one needs a very systematic approach in order to accommodate the different type of variables, different scales of their evolution and the coupling conditions. Thus, it is of advantage to investigate not only “deformation”, but also “transport” of heat, water, vapour or “bio-chemical substances“ as primary processes, and account for “reactions” along with coupling conditions, in computing the limit states (e.g., see paper of Kowalsky *et al*.).

This special issue of the International Journal on Coupled Systems Mechanics deals with a number of different topics on Coupled Systems Mechanics, where mechanical deformations are coupled with thermo-plasticity of metals, hydration, dehydration and aging of concrete with respect to different environmental conditions, and the simulation of long term degradation of landfills. Rather than making a more detailed account of each particular paper, we invite the readers to carry out their own explorations, hoping we addressed the needs of a very large group of readers interested in different multi-physics problems. Last but not least, we would like to thank all the authors in this CSM Special Issue for their contributions to this goal.

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