

Mathematical Research In Materials Science: Opportunities And Perspectives

TOWARDS DATA-DRIVEN MODELING AND SIMULATION OF MULTIPHYSICS DEGRADING SYSTEMS

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ABSTRACT

This paper outlines a methodology for applying a data-driven inverse-problem approach on the area of modeling mass-conserving degrading multiphysics continuum structural and material systems. The methodology is applied on composite materials under simultaneous mechanical and thermal multi-field excitation and is based on mechatronic and computational automation. Furthermore, the multi-domain multiphysics modeling necessary for addressing the fluid-structure interaction involved in such systems is also discussed in the context of jet platforms with aerodynamically induced heating. Finally, simulation demonstrations are also presented and applied for a concept fighter as well as a sensor-driven data solution reconstruction of an aircraft wing.

Introduction

Motivation for research on the characterization of multiphysics degrading systems and its applications stems both from opportunity and need-based contexts.

On the opportunity-based side, recent developments on embedded sensor networks and associated sensor-based technologies allow for data-driven modeling and simulation applications associated with real-time or near real-time material and structural health monitoring systems. Greatly promoting this opportunity is the ever-improving evolution and creation of computational technologies from miniaturization, performance and economic perspectives.

On the need-based side, it is becoming more and more apparent that research and development (R&D) activities in developed economies are driven by motivations asserted by the various stake holders involved in product production and consumption. Producers are interested in tailoring R&D processes to drive various economic metrics such as total cost of production and return on investment towards their benefit. Consumers are interested in optimized economic (i.e. total cost of ownership) and utility based metrics such as functionality, usability, safety and maintainability, thus forcing producers to pay attention into building these properties into their R&D products. Furthermore, today's cradle-to-grave engineering requirements for validated, safe, economic and maximally functional, flexible manufacturing, qualification, certification, utilization and maintenance of system products have significantly raised the demand for validated, efficient and quick simulation of the behaviour of complex whole systems. In the particularly complex category of material and structural degrading systems that exhibit a time-varying behaviour for the large time scale where aging and maintenance are critical, life extension for usability purposes has become a focal area of interest. On the other hand, simulations inherit all of their utility and economic properties from those of the analytical and computational models they are based upon. Data-driven determination of analytical and computational models is an activity that contributes to this end in that it promotes embedding validated realism originating from the measured behavioral characteristics encoded in the systematically collected data.

Research conducted at the Naval Research Laboratory (NRL) for the past forty years within the context of the material constitutive behaviour characterization has been both anticipating and exploiting the computational technologies evolution in a manner that is consistent with the previously mentioned motivational drivers. Similarly, research at Stanford University and previously at University of Colorado at Boulder has focused on generalizing and prototyping multi-domain modeling, algorithmic and computer technologies for multifield fluid-structure interaction applications. The present paper describes an overview of merging both of these efforts under the context of the "Data Driven Environment for Multiphysics Applications" project [1-3].

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