

On the role of hierarchic spaces and models in verification & validation

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Abstract

A fundamental question of computational engineering is whether it is possible to predict the response of some physical system or process to some form of excitation by numerical simulation with sufficiently high degree of reliability to justify basing engineering decisions on the predictions. This problem is receiving a great deal of attention today. It is well understood that numerical simulation involves the formulation of a mathematical model and its numerical solution and that both the model and the approximate solution must be shown to satisfy certain necessary conditions. Validation involves the comparison of one or more functionals that can be observed and measured in a physical experiment with their predicted values. More often than not, the data of interest cannot be observed in physical experiments. Therefore, in the majority of the cases, what is observed in a validation experiment and what the mathematical model is called upon to predict are not the same functionals. In other words, the predictions of the data of interest can be tested by indirect means only.

The errors associated with the choice of the mathematical model are called the errors of idealization. When we compare predictions based on a mathematical model with experimental measurements then we are interested in the errors of idealization. However, since we generally do not know the exact solution corresponding to the mathematical model, we can compare the experiment only with the numerical solution. Therefore, without assurance of the accuracy of the numerical solution (verification) it is not possible to interpret the results of validation experiments properly.

In life prediction of structural components containing an initial flaw it is particularly important to determine stress intensity factors (SIFs) to a high degree of accuracy. Since the exact solution for SIFs are generally not available for cracks in complex geometric features, Beta factors are often expressed as the superposition of the SIFs of several simpler cases, and

beta curves are then compiled as a function of crack length to perform crack growth studies. An alternative to the superposition approach is the development of properly formulated models solved by the finite element method (FEM).

The hierarchic structure of finite element spaces created by the p-version of the FEM is ideally suited for the purposes of verification, since it is convenient and inexpensive to produce converging sequences of functionals and verify that the results are substantially independent of the polynomial degree of elements. It is also necessary for the computer implementation to support hierarchic sequences of models, allowing investigation of the sensitivities of the data of interest and the data measured in validation experiments to the various assumptions incorporated in the model.

This presentation will address the requirements for the proper formulation of mathematical models for the computation of SIFs and their approximation by the FEM within the framework on verification and validation. Aspects of implementation are also discussed and specific examples are presented.