8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

RECENT EXPERIENCES AND FUTURE DEVELOP~~ME~~MENTS ON THE VALIDATION OF FINITE ELEMENT MODELS FOR SPACEFLIGHT HARDWARE

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Key Words: *Model Validation, Uncertainty Quantification, Error Localization, Dynamic Analysis, Buckling Analysis*

ABSTRACT

Uncertainties quantification in simulation results and experimental data is a fundamental aspect in validation of finite element (FE) models [1]. Some methodologies and procedures for model updating and validation of spacecraft structural dynamics models which take into account the uncertainties have been recently developed or funded by the European Space Agency (ESA) [2]. The contribution at WCCM8 intends to provide an overview on the present effort of the Agency and the current status about validation of FE models for spaceflight hardware. It will first illustrate some recent experiences on the validation of FE models carried out both at ESTEC, the European Space Research and Technology Centre, and DLR, Institute of Composite Structures and Adaptive Systems. Then, the main objectives and activities of two other studies in progress will be briefly illustrated. The first study is performed in cooperation between ESA and IfM, University of Innsbruck; the second one is performed by a consortium of European industries and universities under the technical management of ESA.

The first experience which will be presented concerns the so called "error localization" based on sensitivity analysis and optimisation techniques within a stochastic approach [2]. Since the "manual" choice of the "design variables" is often burdensome and suboptimal, the graphical user's interface called "hypergraph", presently implemented in the commercial software code "Ontospace" [3], has recently been evaluated at ESTEC. The hypergraph is helpful in understanding combinations of inputs that will cause certain effects in outputs. Some preliminary conclusions show that, by using the hypergraph, the most effective variables for model updating can be easily identified, allowing easier error localization by sensitivity analysis. Some examples will be presented (Figure 1).

The main objective of the recently concluded ESA-DLR study "Probabilistic aspects of buckling knock-down factors (KDF)" was to achieve improved buckling knock-down

factors for unstiffened CFRP cylinders (including estimation of the KDF via stochastic simulation). Validation of numerical simulation for each manufactured/measured/tested cylinder was performed as part of the study. Indeed it should be noted that the most challenging objective was to validate an approach and a computational methodology more than a FE model for a specific untested spaceflight hardware load case. One of the main outcomes (Figure 2) of the study was that good agreement was not reached between the probability density functions of the experimental and of the numerical buckling loads. Therefore for determining a realistic knock-down factor (for the cylinders under investigation), an experimental buckling test program cannot be substituted by a computational analysis so far.

The objectives of the study in cooperation with the University of Innsbruck, "Model validation and uncertainty analysis of spacecraft structures" are: 1) the development of methodologies and procedures for updating spacecraft FE models, which already capture uncertainties, on the basis of a single test specimen and 2) to directly link the prediction (e.g. accuracy) of the loads acting on the spacecraft (which are calculated via the so called "launcher-spacecraft coupled loads analysis), to the validity (e.g. test-analysis correlation data) of the spacecraft structural mathematical model. The study started in September 2007.

Within the study "Assessment and improvement of dynamic test data" started in December 2006 and performed by the consortium Astrium SAS (F), Intespace (F), University of Kassel (D) and DLR (D), the objective relevant to FE model validation is "to assess and quantify the uncertainty in the spacecraft sine test data". In particular the quantification of uncertainties from the following sources is under examination: 1) specimen/transducer interface (e.g. location and orientation) 2) acquisition chain (e.g. transducer and digitalization), 3) test data post-processing. Other important aspects such as non-linearities in structural dynamics (e.g. sources, detection, characterization, and quantification), force measurement at spacecraft-shaker interface and sine sweep rate effects, are also under investigation.

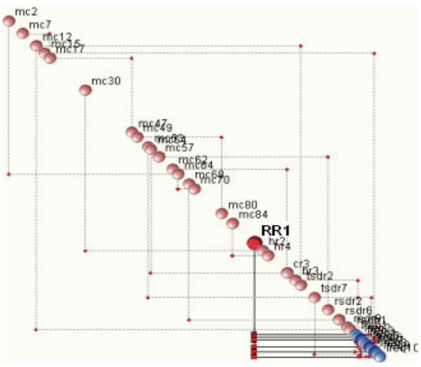

Fig. 1 - Example of hypergraph

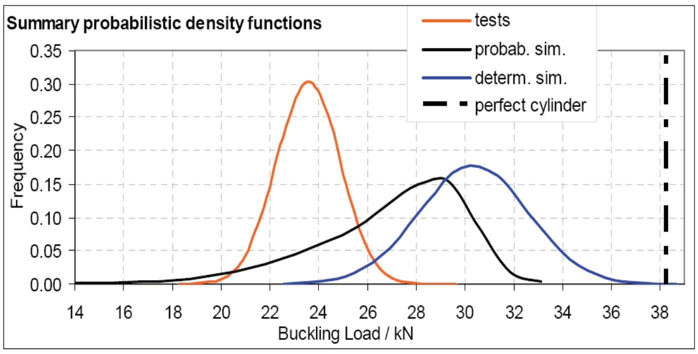

Fig. 2 - ESA-DLR study summary results

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