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VERIFICATION & VALIDATION OF MODELS

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Summary

This presentation considers the issues involved in verifying and validating FE models, with a particular emphacis on validation.

Design Substantiation by Numerical Analysis

Numerical Analysis is increasingly being used as the only substantiation of design of structures and components subjected to extreme loads.

- **This is particularly the case in civil engineering safety critical structures such as:**
  - **Civil nuclear containment plant;**
  - **Offshore oil and gas installations; and**
  - **Process chemical plant.**

Design to hazard loads, such as fire, explosion and earthquake is usually carried out with load factors of 1.0, therefore reducing any inherent "codified" safety margins.

Design Substantiation by Numerical Analysis

It is therefore necessary to take steps to demonstrate that the results of the analysis used as the basis for the substantiation of the hazard resistance is reasonable.

Demonstration that the software employed has been reasonably verified. *(Installation tests DO NOT constitute verification)*

Demonstration that the analysis techniques, the analysis models and the analysis results are all valid in the context of the structural system being performed.

Verification and Validation

Definitions of Verification and Validation in the Numerical Analysis Context

<u>Verification</u> is defined as the demonstration that the mathematical and logical functions necessary to analyse a physical system to an acceptable accuracy are correctly executed; and that they correctly implement the theory upon which they are based.

<u>Validation</u> is defined as the demonstration that the derivation and selection of mathematical models and solution algorithms to analyse a given physical system are based on sound and justifiable assumptions and approximations.

QA Manuals

Most Quality Management Systems will require that Finite Element Analyses should be verified, but few will require validation.

This may be due to ISO9001 specifically identifying verification but not validation.

Verification often takes the form of formal checking of input decks and model generation calculations. QMS procedures do not always demand that the logic applied to the analysis is reviewed by a senior analyst to ensure that the correct analysis procedure is being used.

Validation is a tool that can provide a means of overcoming such deficiencies and allow engineers without an in-depth analysis background assess model results. In addition it will point to problems with the analysis software.

Verification

Validation is in the hands of the analyst, whereas verification is primarily a developer task. ISO9001 calls for all software used on projects to be verified, with the onus being placed on the user to demonstrate that adequate verification has been performed.

(It should be noted that if a developer is not able to provide evidence of verification, to satisfy ISO9001, the user should carry out sufficient verification exercises to the demonstrate veracity of all program options to be employed on projects.)

The Hidden World of the GUI

The advent of the Graphical User Interface (GUI) has hidden some of the complexity and even mystique of the numerical analysis systems.

The GUI is designed to make the program easier to use and therefore more accessible. In doing this it adds a sense that it is holding the users hand, and if the program doesn't complain then the model is OK.

Classification and Handling of Warning and Error Messages

Software developers are caught between a rock and a hard place with error trapping:

- **Classify all non-standard usage and exceedance of verification and validation bounds as Errors that stop the execution and you upset the power users; and**
- **Classify transgressions as Warnings, write the warnings to a file and they get ignored by many users, especially the occasional user.**

The fact that the GUI allows a model to be executed is often seen as confirming that the model is error free.

How to Validate

Designing an analysis procedure that "builds" to the ultimate solution, for example a non-linear transient analysis:

- **Bounding hand calculations to establish a "feel" for the likely mechanics;**
- **An elastic mode frequency analysis to establish the initial dynamic response;**
- **A linear time-domain solution to identify the path to the first non-linear response;**
- **The non-linear time-domain solution; and**
- **Backtrack to look for evidence of the earlier results in the final results, OR to explain why these results are not present. (Both constitute validation.)**

How to Validate

There is no one correct method for validating a model, the nature of the validation necessary will often be dictated by the nature of the problem being solved.

Engineering judgement plays an important role, however it often necessary to write the judgements down.

Identification of bounds to the problem using hand calculation and simplified analysis

What Should be Validated

"Ideally" the validation exercise should consider all aspects of the modelling that influence the analysis results, for instance:

- **All modelling assumptions, including selection of analysis technique;**
- **All boundary conditions;**
- **Nature of loading and the manner in which the loading is applied;**
- **Modelling and analysis parameters;**
- **Overall solution quality; and**
- **Odd and anomalous results.**

Control of the Validation Process

The validation process should be lead by a senior engineer with a sound track record in the particular engineering field of interest.

This lead engineer:

- **Does need to have product experience;**
- **Does need to be able to identify flaws in the results presented;**
- **Does NOT need to have ANY experience in computer-aided numerical analysis, indeed the more cynical the better.**

Summary

To sum up in terms of the FENET Education & Dissemination Theme:

There is a need to adopt standard definitions for Verification & Validation – These may differ between development & application.

There is a need to convince users to validate models as a matter of course. Validation is an on going process within the progress of an FE Model. This needs to begin during degree courses.

There is a need to urge users to assess the range of Validity of analyses – especially complex ones.

Final Thought

A model that is too complex to validate,

by definition has to be considered invalid