Smart Engineering Simulation Apps

Democratization of numerical simulation through the development and dissemination of expert-designed Smart Engineering Simulation Apps is gaining momentum; however to ensure the level of reliability expected in professional practice, such apps must incorporate solution verification which is an essential technical requirement of Simulation Governance.

What are Smart Engineering Simulation Apps?

Smart Engineering Simulation Apps (Sim Apps) are FEA-based software tools that support standardization and automation of recurring analysis tasks and process workflows for use by non-specialists. They are designed to fit into existing analysis processes, capturing institutional knowledge, best practices and design rules. An example is the aircraft structural bolted joint shown in Figure 1.

Sim Apps can be used and shared by engineering groups in different geographic locations to produce consistent results by tested and approved analysis procedures, regardless of the level of expertise and experience of the user. When they meet the technical requirements of Simulation Governance, Sim Apps are "smart" in the sense that their embedded intelligence enables Simple, Accurate, Fast, Efficient, and Reliable (SAFER) simulations with built-in quality assurance.

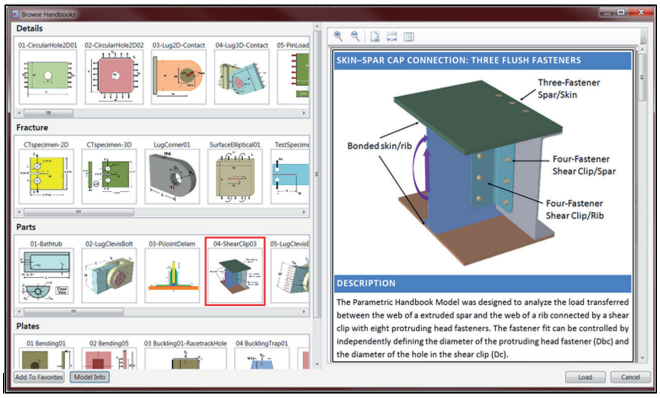

Figure 1 - Sim App example: Parametric model of an aircraft structural bolted joint

Why Simulation Governance?

Simulation Governance is a managerial function concerned with the exercise of command and control over all aspects of numerical simulation through the establishment of processes for the systematic improvement of the tools of engineering-decision-making over time. The key elements of simulation governance are Verification, Validation and Uncertainty Quantification (VVUQ).

Verification is concerned with the accuracy of the numerical solution of mathematical models and encompasses code verification, data verification and solution verification. Whereas code verification is the responsibility of the code developer, data verification and solution verification are among the responsibilities of the users. In the application of established design rules, data verification and solution verification are essential; the goal is to ensure that the data is used properly and the numerical errors in the quantities of interest are reasonably small. Given the growing reliance of simulation-driven design early in the product development cycle, it is simply no longer sufficient to neglect solution verification and only perform validation late in the cycle during physical testing or prototyping.

Engineering simulation apps for standardizing recurrent analysis processes must be developed under the framework of Simulation Governance for users who do not have FEA expertise; they must possess built-in safeguards to prevent use outside of the range of parameters for which they were designed; must incorporate automatic quality assurance procedures; and must be deployed with detailed description of all assumptions incorporated in the mathematical model and the scope of application. Estimation of relative errors in the quantities of interest is an essential technical requirement of Simulation Governance.

One argument often used to justify the lack of error estimation is that rules established by the experts are sufficient, and that the "user can always consult with an expert if the results are wrong". The problem with this argument is that if the assessment of the quality of a solution depends on the subjective opinion of the expert analyst, the same expert opinion is needed to determine when the solution is wrong. A non-expert user is not qualified to make that determination. Having an automatic solution verification feedback for all the quantities of interest however, allows non-expert users to consult with experts when the computed data does not converge to within the prescribed tolerance. Engineering simulation apps should not be deployed without objective measures of quality for all quantities of interest.

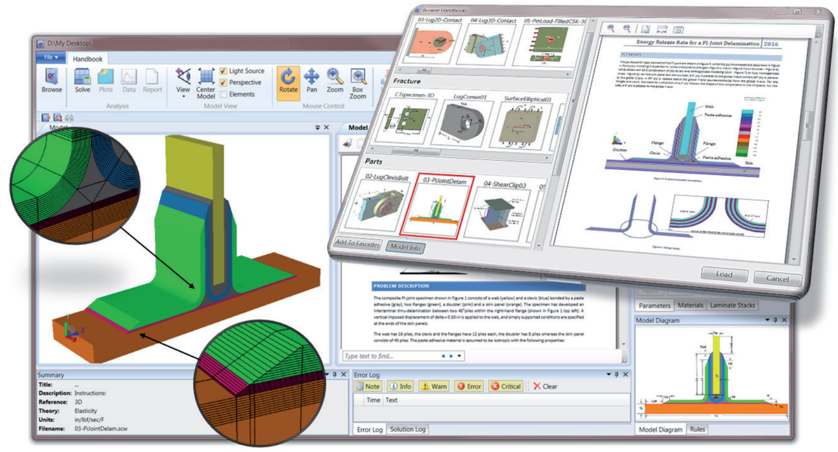

Figure 2 - CAE-Handbook hosting a portfolio of Sim Apps

Why use Simulation Apps?

Proper application of numerical simulation procedures requires expertise in computational engineering that is not widely or readily available. Standardization deployed by means of Smart Sim Apps can leverage this expertise for recurring analysis tasks and process workflows similar to the expertise of specialists in applied mechanics made available through classical engineering handbooks.

Because classical handbooks present results for parameterized problems solved by classical methods, they have limitations in model complexity and scope. FEA-based Smart Sim Apps developed by expert analysts on the other hand deploy verifiable solutions obtained by numerical means allowing models of much greater complexity to be deployed for users who do not need to have the same level of expertise in numerical simulation technology. Thus design engineers earlier in the cycle may begin to harness the power of simulation with less technical risk and greater confidence.

What are the benefits of using Simulation Apps?

The benefits include: (a) making difficult classes of simulation problems easier, faster, and more accurate to solve by the specialist to support increasing complexity of products and the demands of shorter design cycles, (b) making routine design analysis problems solvable by designers and engineers as they did for years when relying on handbooks and design curves produced by methods groups, and (c) empowering new engineers to become productive sooner by providing access to reliable tools that have captured institutional knowledge and best practices of the organization.

An example of Sim App implementation is the portfolio of Simulation Apps shown in Figure 2. The user can examine each model by clicking on an icon on the left panel of the browser while the corresponding detailed information is being displayed on the panel on the right. For each app in the portfolio a simple 3-step operation is required to obtain results: Select – Update – Solve.

Once a Sim App model has been selected, it is loaded into the user interface of the host program, in this case the CAE-Handbook shown in the figure. The user can update the model by modifying the parameters available for changing dimensions, magnitude and direction of loads, material properties, laminate ply layout, and any other attributes exposed by the Sim App model creator. The e-Handbook checks for consistency of the input parameters and warns the user if any rules were violated. The rules governing the relation among parameters are available for review by the user at any time.

Once the input parameters are entered and verified the user simply performs a pre-defined solution and the results are presented in the form of a report, contour plots and convergence information.

While the above process looks straightforward to implement, it is not. There are numerous challenges with employing traditional finite element analysis tools that will be addressed in a future article on the technical requirements for robust and reliable Sim Apps.

Concluding Remarks

FEA-based Smart Engineering Sim Apps are software tools that standardize and automate recurring analysis tasks for use by non-experts. They are designed to fit into existing analysis processes that capture institutional knowledge, best practices and design rules.

Since the finite element method is a numerical procedure to find an approximate solution of a mathematical model, extreme care must be given to any simulation tool which may be employed by a non-expert. Automating simulation without providing the user with an explicit, objective measurement of the quality of the approximate solution is simply dangerous.

When Sim Apps are designed within the framework of Simulation Governance, they are "smart" because their embedded intelligence enables simple, accurate, fast, efficient, and reliable (SAFER) simulations with built-in quality assurance.

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