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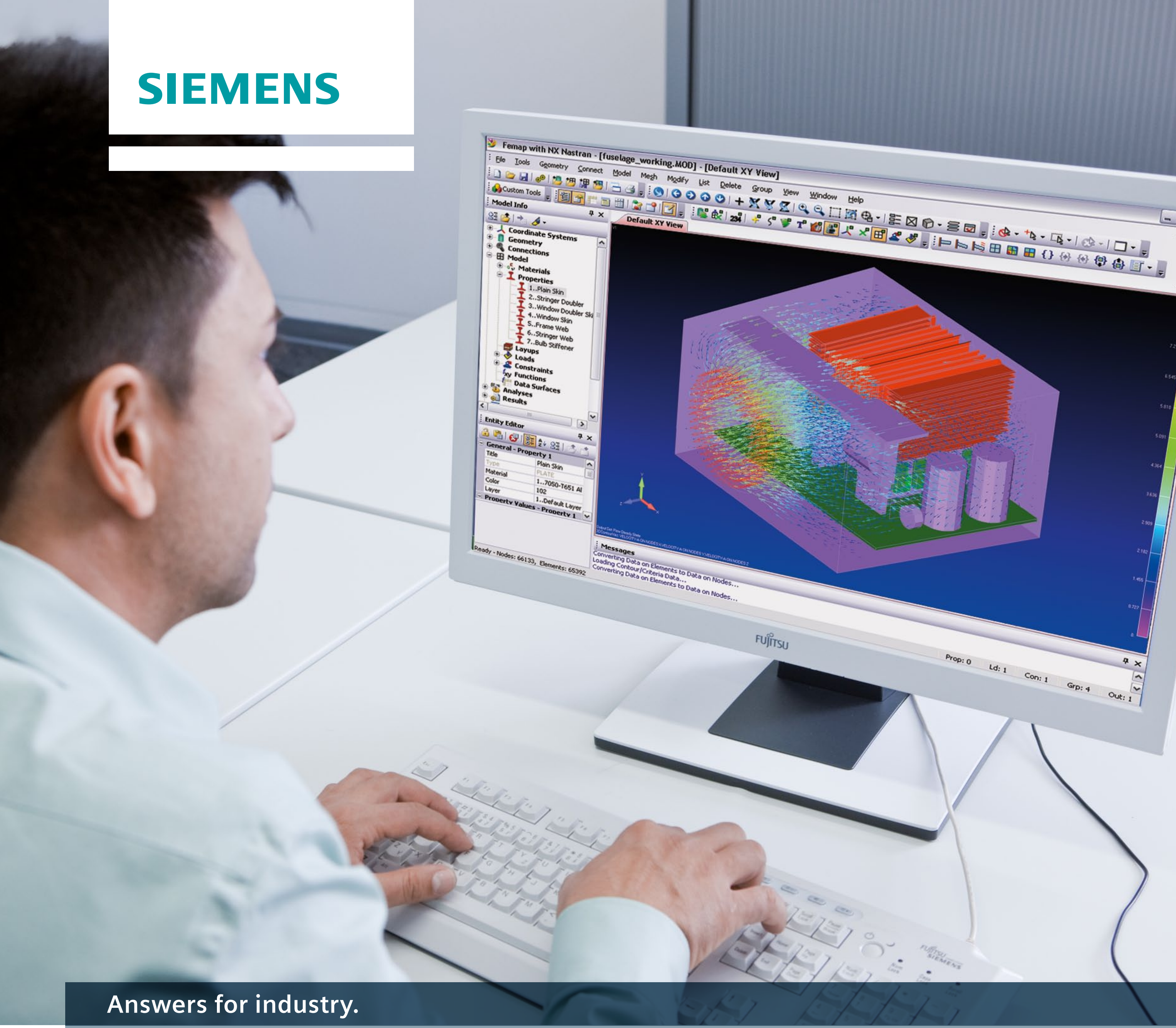

Answers for industry.

Buyer's guide for FEA software

Tips to help you select an FEA solution

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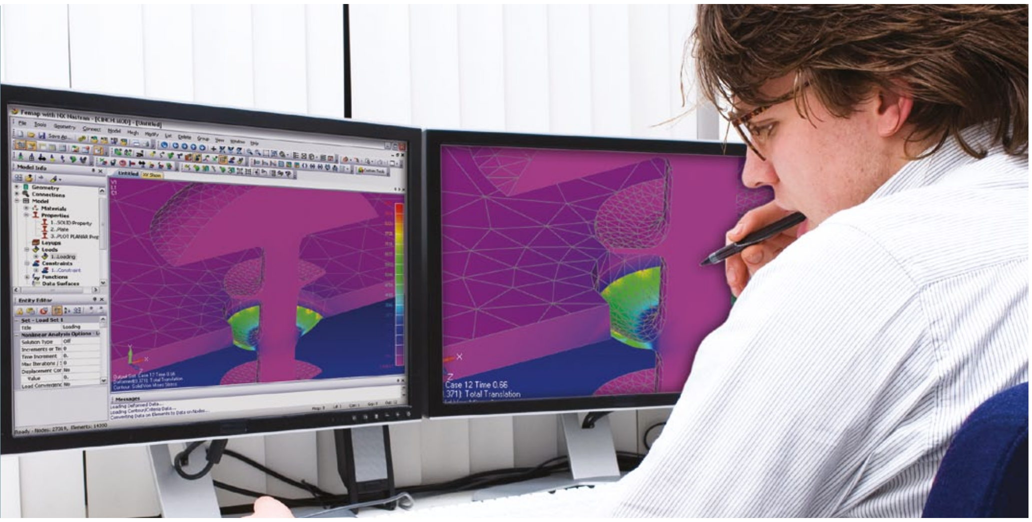
To enable effective finite element modeling and analysis, don't overlook the pre- and postprocessor part of the solution. This document gives you insight into what to look for and the many advantages that accrue from using a world class pre- and postprocessor.



"The benefits [of using a powerful pre- and postprocessor] include a significantly reduced error rate for designs, greater product quality, and elimination of repairs during manufacturing and substantially reduced costs."

Cui Zhongqin
Chief Engineer
Baotou Hydraulic Machinery

In selecting a finite element analysis (FEA) software solution, it is crucial that you consider the pre- and postprocessor, which can be critical for the analysis speed and accuracy. FEA analysts rely on the pre- and postprocessor to work with an assortment of data files, provide a variety of ways to idealize the model, support one or more solvers and produce the data and reports that are needed to meet both internal and external requirements. Engineering managers rely on the pre- and postprocessor solution to reduce the risks associated with accuracy while meeting time-critical product development deadlines.

Although FEA solvers are tasked with providing accurate results quickly, the role of the pre- and postprocessor should also be considered. The pre- and postprocessor enables you to idealize a product model based on geometric information and then simulate how that model will behave under certain real-life conditions. The degree of control offered by the pre- and postprocessor is vital to increasing model quality while decreasing analysis time. The risks of poor model quality and accuracy increase as models and analyses grow in complexity.

This guide presents the critical role of the pre- and postprocessor in improving the accuracy of FEA results and making the most of engineering resources. Read this guide to find out more about these top considerations:

- Accuracy
- User interface
- Accessing CAD data
- Understanding the results
- FE model creation and Idealization
- Automation and customization
- Solver support and solution scalability
- Overall value and support

Role of the pre- and postprocessor and the FEA process

The greatest challenge for engineering managers is mitigating the risks inherent in any new product design. FEA technologies help enable significant reductions in risk, which is why they are so widely used. Industry-leading pre- and postprocessing can provide an additional order-of-magnitude gain in analyses. The gains are in accuracy and control – simplifying and cleaning up the geometry and the discretized data that goes into creating the finite element model and ensuring that the calculated results are both understandable and relevant. Figure 1 illustrates the role of the pre- and postprocessor and solver in the product design process.

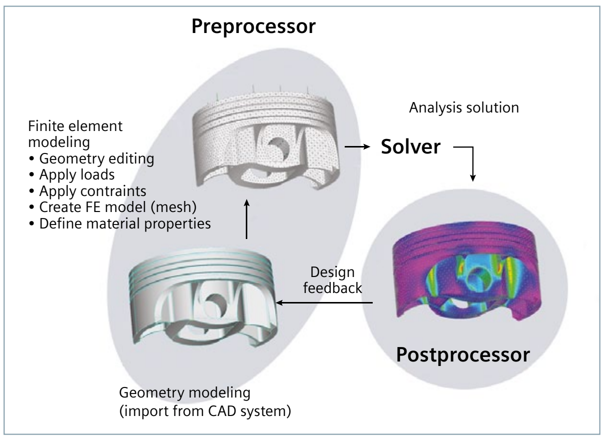


Figure 1: The finite element analysis process.

The role of the preprocessor, as seen in figure 2, is to import the geometry data, correct the geometry and discretize or mesh it in order to idealize a physical design and create an FE model for analysis. Automation and customization capabilities provided by the preprocessor can help to speed up this process. Following analysis by a solver, the postprocessor imports and displays the results in a graphical format and helps the understanding of model behavior. With a good understanding of the performance of the design from the analysis, the analyst may return to the preprocessor to further refine the model if necessary, and rerun the analysis.

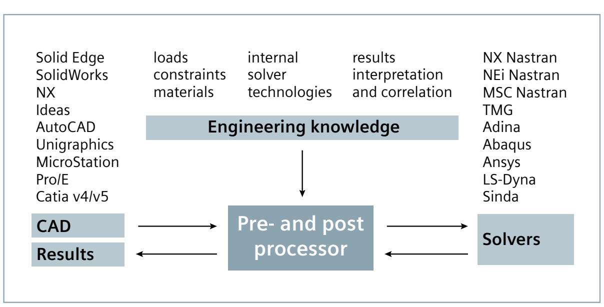


Figure 2: The role of the FEA pre- and postprocessor.

The importance of meshing the FE model cannot be understated for both accuracy and speed. Figure 3 illustrates a mesh convergence analysis in the preprocessor which can help determine an ideal mesh size for an analysis thereby minimizing runtime while conserving accuracy. In a report titled "Cost Saving Strategies for Engineering: Using Simulation to Make Better Decisions," researchers at the Aberdeen Group, Boston, found that engineers at 61 percent of the report's "Best-in-Class" companies had significant control over meshing elements and his control was a contributing factor to the companies' success. See a link to this report in the Other resources section.

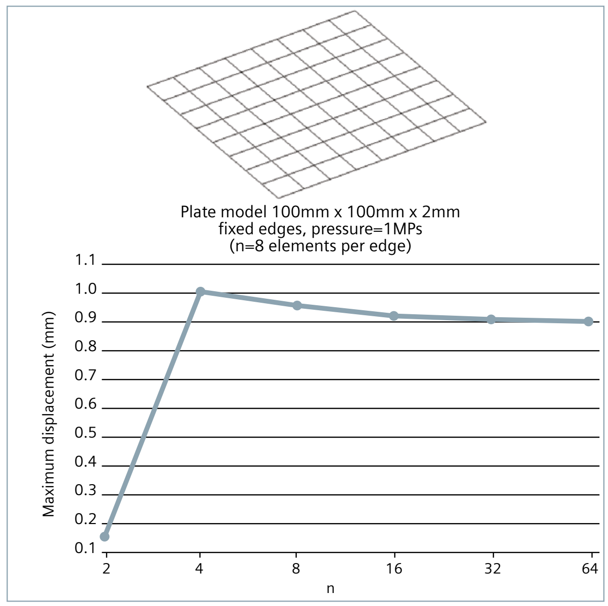
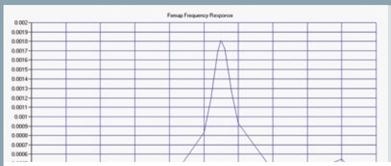


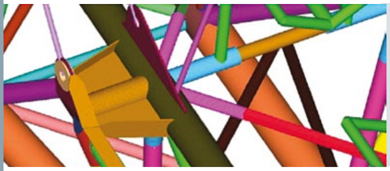
Figure 3: Mesh convergence analyses can help determine the required model size to ensure accurate results.

Key questions for your software vendor

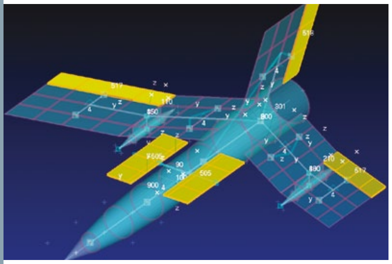


Accuracy – Does the pre- and postprocessor enable you to control the FE model creation process sufficiently to ensure the creation of efficient FE models without sacrificing accuracy?

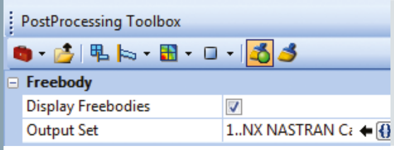
Accessing CAD data – Can the pre-processor import and manage geometric data from multiple CAD systems and data formats?



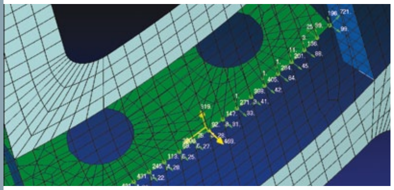
FE model creation and idealization – Does the pre- and postprocessor allow you to idealize certain topologies such as thin-walled models, and create smaller, more accurate finite element models?



Solver support and solution scalability – Does the pre- and postprocessor support the export of solver input files and the import of solver results files? Can it support the parameters needed by industry-leading solvers? You should not only consider your current analysis needs but also comprehend the potential scalability of the solution as new and unforeseen factors may lead to additional simulation requirements in the future.

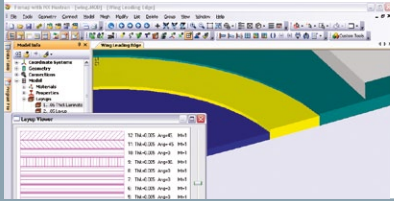


User interface – Does the user interface promote productivity in the use of the software and expedite learning?



Understanding the results – Given the potentially huge amount of data that can be created by a finite element solution, it's important to be able to quickly interpret results and gain an understanding of the model's behavior for a quick analysis turnaround.

Automation and customization – Does the pre- and postprocessor have built-in toolkits, macro creation capabilities and an application programming interface? Is knowledge capture possible and can workflows be automated and adapted to the organization's processes? A pre- and postprocessor should be able to automate time-consuming tasks while also allowing the analyst to retain control of the adjustments made to the model and the steps of an FEA analysis. Can the pre- and postprocessor interact with third party programs?



Overall value and support – Does the pre- and postprocessor vendor provide sufficient support to ensure maximum productivity? Does the vendor release regular software updates and do they provide useful new capabilities as well as error fixes?

Top pre- and postprocessor considerations

"Creating advanced models that are both accurate and fast definitely gives us a competitive edge and has become a critically important contribution on these fast-paced, technically challenging spacecraft projects."

Jeff Preble
President
SpaceWorks Engineering

"One single beam element replaces hundreds of solid elements. This is a definite advantage of Femap. You can start your model from nodes and elements and not just from solid geometry."

Alexander Naatje
Project Engineer
Femto Engineering BV

"Other products focus on automatic meshing of complex mechanical components, which Femap can do. But if you tried to do that with something as big as a [drilling rig] hull, your model would be composed of solid elements, which would be much too large. Modeling with beams and plates is a better approach, and something that Femap strongly supports."

Timo de Beer
Principal Structural Engineer
GustoMSC

These top considerations provide more information and answers to the key questions to ask your software vendor when selecting an FEA solution.

Accuracy

The preprocessor should provide the ability to fully control creation and adjustment of the finite element mesh. That is, meshing toolboxes should be available to help create properly sized and shaped elements in the right locations to ensure that the final model will produce accurate results efficiently.

Accessing CAD data

It may be possible to take advantage of the CAD model of the design to be analyzed, and use it to create a finite element model. To this end, CAD data can be imported for meshing and idealization. CAD neutrality is important for a standalone pre- and postprocessor, as there are many different CAD programs and data formats. The preprocessor should be able to import geometric data from all leading CAD software packages including Solid Edge® software, SolidWorks, Autodesk, NX™ software, Pro/Engineer, Catia and I-deas™ software. The preprocessor should also be able to import CAD geometry represented by industry-standard data formats, including Parasolid®, ACIS, STEP, IGES, VDA and DXF.

FE model creation and idealization

FE model creation is a crucial part of the simulation process and impacts both analysis accuracy and efficiency. Problematic CAD geometry, such as the existence of small curves or sliver surfaces, is one of the greatest obstacles encountered in generating an FE model from a CAD model. Left untouched, these and similar geometry errors will degrade mesh quality and ultimately reduce results accuracy and solution efficiency. The preprocessor should be able to efficiently detect all such geometric irregularities and repair or remove them from the model completely, while ensuring that there is no consequential loss of other associated model data, such as boundary condition definitions.

In addition to CAD data access and import, the pre- and postprocessor should also have the ability to create and manipulate geometry and finite element entities in the absence of any geometry.

The time taken to perform an analysis is directly proportional to the model size as shown in figures 4 and 5. Model size is dependent upon the number of node points and their associated degrees of freedom in a model. Certain topologies can be idealized to significantly reduce model size without compromising accuracy. For example, thin-walled structures can be represented by fewer two-dimen-

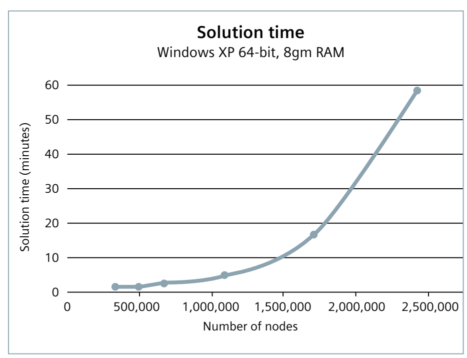
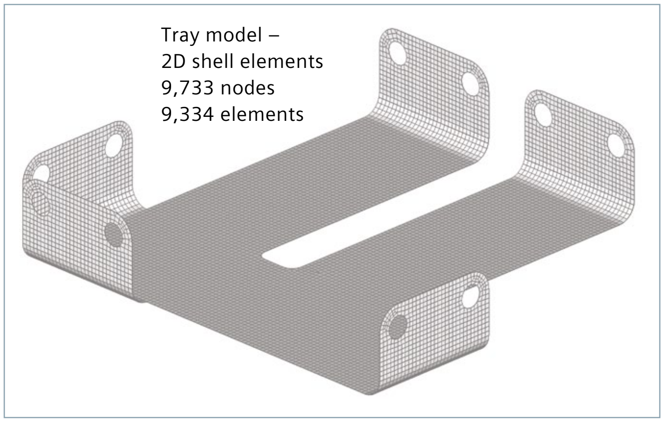


Figure 4: Solution time vs. model size.



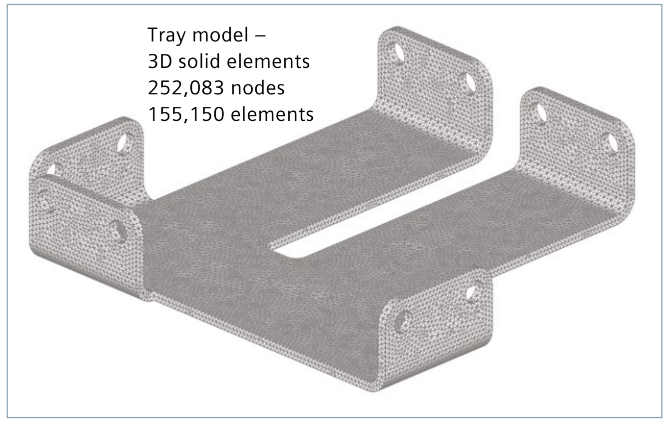


Figure 5: Thin walled model size comparison.

sional shell elements instead of many solid elements. Similarly, long slender topologies can be modeled using one-dimensional beam elements which produce a much smaller FE model without losing accuracy. The preprocessor should provide the means to idealize geometries through capabilities such as mid-surface extraction that allow thin-walled solids to be meshed with shell elements. Beam modeling tools should also be provided.

Solver support and solution scalability

To solve for various types of physics, such as mechanical, fluid flow, or crash analysis, a pre- and postprocessor should integrate with and support the main industry solvers including NX Nastran® software, NEi Nastran, MSC Nastran, TMG, Adina, LS-Dyna, Ansys, Abaqus and Sinda. The pre- and postprocessor should also support FE model definition and analysis control parameters in the creation of the solver input file, as well as importing results data after solution.

Each of the solvers mentioned above provide a number of different solutions. Typically, analysis types include:

- Linear statics, i.e. static loads and constraints
- Normal modes, i.e. natural frequencies of vibration
- Linear buckling
- Dynamic response to a transient or frequency based loading
- Heat transfer, both steady state and transient
- Optimization of model parameters to minimize weight
- Nonlinear to solve for effects such as large displacement, nonlinear materials and contact
- Explicit solutions for nonlinear crash analysis
- Rotor dynamics for rotating parts
- Composite materials
- Aeroelasticity to simulate effect of an airstream on a structure
- Fluid dynamics and fluid flow analysis

With some solvers much of this advanced functionality is presented in modules available for purchase in addition to a basic FE package that is usually limited to linear statics, modes and buckling solutions. The more advanced functionalities should be supported by the preprocessor. The more such capabilities are supported, the more scalable is the solution. Scalability allows you to attempt more advanced analyses as your knowledge and expertise increases. It also allows the purchased product configuration to be expanded when the need to perform more advanced analyses arises.

User interface

The user interface of the pre- and postprocessor should be easy to learn and use, promoting productivity. Adoption of popular and commonly used interface types such as Windows can help the usability of an interface. Customization is also important, such as the ability to tailor the user interface to your needs and allow commonly used tools and functions to be reached easily while de-emphasizing seldom used features.

Understanding the results

Each time an FE model is solved, it can help create a vast amount of results data. The ability to process the data and quickly gain an understanding of the model behavior is important for a fast analysis turnaround. The postprocessor should therefore allow full control of results selection and include a robust and varied set of tools to manage and display results, while at the same time facilitate easy comprehension of the data. Results viewing becomes more complex with highly idealized models, so the postprocessing tools should provide the ability to easily view appropriate results quantities on shell and beam elements.

Automation and customization

More advanced and involved solutions invariably demand the ability to modify or enhance the simulation approach. Also, in setting up a model for analysis, there are often repetitive sets of commands that would be laborious to complete without some method of automation or knowledge capture. Interaction or data transfer with third party software products such as Word and Excel is also important. The customization capabilities of a pre- and postprocessor application programming interface (API) and macro programming capabilities are invaluable in managing these challenges.

Overall value and support

Separate and distinct from questions about pre- and post-processors is an assessment of the company behind the software. This goes far beyond financials and similar statistics. For example: does the company offer a ready-to-go system delivered with software, manuals, guides and security devices? Will additional purchases be required?

Keeping a pre- and postprocessor up to date and operating it effectively raises additional questions beyond the initial buying and installation concerns. What is included in maintenance and support packages? What are the hours of application engineering (AE) support by telephone? What are the terms and costs for an AE onsite? Is there a trial version with free support? Is there a useful web portal? What about the availability of bug fix releases of the software?

Conclusion

Without question, the choice of analysis solvers must be carefully considered. Equally important is the choice of a pre- and postprocessor. There are many practical questions that need to be asked and answered to ensure you have a complete solution that provides timely results while reducing the risks of poor model quality and accuracy.

Glossary

Analysis – the finite element calculation by a solver such as Nastran.

Beam elements – one-dimensional finite elements that represent bar-like or beam-like structures.

Boundary conditions – where and how the part or assembly model is held or constrained, such as mounting surfaces or fixtures that do not bend or deform.

Buckling – an analysis to determine the buckling load of a slender structure subjected to compressive loading and where the load at failure is less than the ultimate compressive load that the material can withstand.

CAE – Computer-aided engineering.

CFD – Computational fluid dynamics, fluid flow analysis such as electronic component cooling.

Design optimization – an analysis that automatically varies model parameters or element property values (such as plate thicknesses) to reduce stiffness (and hence material and weight) as much as possible within a prescribed set of allowable stress values or displacements.

Discretization – a term used to describe the process of breaking up a geometry model into discrete elements. See also Meshing.

Dynamic response – an analysis that is performed in the frequency or time (transient) domain, in which the output values vary with respect to frequency or time.

FEA – Finite element analysis.

Finite element – a small regularly shaped representation of geometry for which the stiffness can be mathematically calculated. Multiple elements can be joined together to build a complete model, and all the element equations (associated with the unknown degrees of freedom) assembled for solution by a computer.

Finite element modeling – the process of creating a finite element model representative of the structure of the part or assembly, with definitions for all relevant loading and constraint conditions that reflect the working environment of the design. Typically the FE model is created from the CAD geometry by meshing the CAD model and creating a continuous connected set of finite elements that collectively form the same topology.

Fluid dynamics – simulation of fluid flow over or within a structure (e.g. air flow over a wing of a plane).

Frequency – the property of occurring at frequent intervals, e.g. a musical note has a certain frequency, measured in cycles per second or Hertz (Hz). The frequency of the Earth rotating about its axis is one cycle per 24 hours or .00278 cycles per second.

Frequency response – a dynamic analysis performed in the frequency domain to investigate the dynamic response of a structure subjected to frequency based loading, e.g. the effects of frequency based road loading on the suspension and body structure of a car.

Glossary

Heat transfer – an analysis to determine how heat transfers across a structure from a heat source. The resulting temperature map across the model is usually input into a subsequent structural analysis to investigate the structural loadings and response due to thermal expansion or contraction.

Linear – an analysis used when a structure (such as a beam) or material behaves proportionately to applied loads. As long as the loads do not exceed the material's elastic limits, the structure or material will not permanently deform, and it will return to its original shape when the loads are removed.

Load or force – defined by magnitude and direction, how much and where a force is applied.

Mechanism – rigid body motion, i.e. the ability of a model or part of a model to move without restraint, i.e. mechanisms such as pinned joints that are free to rotate.

Meshing – a term used to describe the process of discretizing or 'breaking up' the geometry model into finite elements to create the finite element model. The mesh can comprise 3D solid elements (hexahedral, pentahedral and tetrahedral), 2D plate elements (quadrilateral and triangle) and 1D beam elements.

Modal – the predisposition of any object to vibrate at certain frequencies, e.g. the motion of a plucked guitar string, which has a certain shape and vibrates at a specific frequency or note. Modal analysis predicts those characteristic frequencies and deformed or mode shapes.

NASTRAN – the acronym for NAsa STRuctural ANalysis, a structural analysis program originally produced in the 1960's for NASA to predict the behavior of the Saturn V rocket during launch.

Node – a point in 3D space to which a finite element is connected and at which output displacements are calculated. Usually a node is the corner point of an element but nodes can also be placed in the centers of element side faces of the centers of their edges.

Nonlinear – model behaviors displaying large deflections that cannot be defined within linear theoretical limits; the material is loaded beyond its elastic limits, then deforms and will not return to its original shape. Nonlinear problems can include contact issues (gaps in geometry that open or close under load) and the use of materials whose mechanical properties cannot be defined by linear stress vs. strain relationships, as the stresses and strains are not proportional.

Optimization – See Design optimization.

Postprocessor – software to display and review the results of a finite element analysis.

Preprocessor – software to create and prepare the finite element model, loads, and boundary conditions and analysis parameters.

Statics – linear analysis comprising loads and constraints that do not move. Static analyses simulate the behavior of an object or assembly under applied loads and constraints.

Transient dynamic – a dynamic analysis performed in the time domain solved at distinct time steps to investigate transient effects of a time-based loading such as an impulse load.

Other resources

Aberdeen: Cost saving strategies for engineering white paper

This white paper offers guidance on how you can use simulation to make better engineering decisions. Also available is an exclusive video that presents key takeaways of this white paper, presented by the author.
www.plm.automation.siemens.com/en_us/products/velocity/femap/cost-saving-engineering.shtml

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FEA for all engineers white paper

Manufacturers are seizing the opportunity to improve their product development process with investments in CAE applications over the next several years, according to AMR Research. The objective of this investment is to bring product design and engineering closer together in order to reduce product development cycle times for more efficient use of engineering resources, to reduce costs and create products that are more likely to meet customer requirements.
www.plm.automation.siemens.com/en_us/products/velocity/femap/forms/fea_for_engineers.cfm

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Top 10 reasons to upgrade to Femap white paper

Industry pressure to reduce costs and improve quality is driving growth in the use of digital simulation throughout the product lifecycle. Choosing the right tools is the key to achieving the business benefits of digital simulation.
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Try Femap with NX Nastran and explore the state-of-the-art modeling functionality of Femap with the powerful analysis capabilities of the industry-leading NX Nastran solver. See how these comprehensive simulation and analysis applications can help you save money and reduce time-to-market through optimized designs, reduced prototyping and physical testing.
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