Efficient Preprocessing Using scFEMod\textsuperscript{(TM)}

A preprocessor for interactively correcting, completing and validating FE models
Overview

This White Paper describes how you can use scFEMod to make the preprocessing of FE models more efficient. It explains the scFEMod concept, its use and advantages.

In the development of complex structures it is becoming increasingly common to link individual components into complex FE models. You need to be able to quickly exchange individual components with variants. For this you need a tool that can efficiently assemble the individual meshes into a single model before simulation begins, without the need to completely remesh the revised CAD model. Modern FE solvers handle this by being able to directly model joining techniques such as welding and the use of adhesives.

scFEMod is a preprocessor for assembling existing FE models, and completing, verifying, and correcting them. Automatic methods let you quickly model spotwelds, weld seams and adhesive bonds and insert rigid bodies. Non-structural masses can be easily added. Errors in meshes, such as flanges that are too close, can be detected and corrected automatically. You can easily recognize and correct unlinked flanges or faulty links. scFEMod is not restricted to specific solvers or computer platforms.

By using scFEMod you can drastically shorten the time needed for preprocessing and model verification, and significantly reduce the number of faulty FE calculations. Having a variety of methods for model verification means that you can avoid using the time-consuming initial phases of the simulation for error correction. scFEMod's built-in automatic mechanisms, a modern GUI and advanced visualization techniques enable you to process FE data quickly and accurately.

scFEMod was developed to satisfy the needs of calculation engineers in the automobile industry, but it can be employed anywhere where FE models need to be assembled, completed, corrected and verified before simulation. It can be used in the crash and noise vibration harshness (NVH) environments and in any other areas where independently meshed structures are combined before computation.

This White Paper is intended not only for engineers but also for managers who want to understand how scFEMod works and how they can use it to speed up their development process.
Improved flexibility in FEM processes

The increasing performance of hard- and software has led to a continual growth in the complexity of models, and to the fact that a higher number of calculations can be made in a given time. This has enabled calculation engineers to optimize structures by repeating computations with different variants of components. A prerequisite for efficiently re-placing components is the modular construction of the complete model from components that are meshed independently from one another.

Up to now, components had to be assembled prior to simulation in such a way that they shared common boundary nodes. Each time a component was replaced by a variant, the boundary nodes of the individual components had to be merged with the surrounding mesh in a time-consuming process, or the entire model had to be remeshed. Modern FE solvers are now able to directly model connection techniques such as welding and adhesion. Instead of the time-consuming remeshing in the area where the components are linked, you only need to specify linking information.

This linking information could come from the CAD model, but it is often not available in the prototyping stage or it is incorrect and first has to be corrected. It often happens too that geometries don't match. When components are independently meshed, it's unavoidable that mesh elements in close proximity to one another overlap, despite the CAD model being correct. This means you have to correct the node coordinates. Another aspect is that in early development phases it can be advantageous to represent components that are not yet meshed through masses or rigid bodies.
The scFEMod software is tailor-made to handle these tasks. It can be used to quickly and efficiently assemble independently meshed components, and correct, complete, and validate them.

Advantages

**Shorter design cycle and lower costs**
Assembling the components takes only a fraction of the time that remeshing them would.

**Better products**
The uncomplicated way of handling component variants means you can improve the product quickly.
Perforation and penetration using a shell-element example. Despite correct CAD geometry, it can happen that FE meshes touch (peretration) or pierce (perforation) one another.

When components are meshed independently, if often happens that FE meshes are created that are incompatible with one another. scFEMod allows you to quickly recognize, visualize and correct incompatibilities. In early development phases, the geometries of the CAD models often don't exactly match, particularly when you are using parts from an earlier model. You have to correct the corresponding meshes to obtain, for example, reasonable spacing between the flanges for welding joints and adhesive bonds.

Also, despite correct CAD geometry it is unavoidable that during discretization meshes are created whose elements touch or overlap. If elements penetrate or perforate one another, additional forces are created that falsify the result of the simulation.

Using scFEMod you can detect, display and correct incompatible meshes even before the first simulation.

Penetrations and perforations can be immediately recognized. Intelligent heuristics allow scFEMod to automatically recognize potential flanges or areas having inadmissible spacing. You can use parameters to automatically or manually adapt these heuristics to the scale of the model. The latest algorithms make this possible in real time, even in complex models.

Unaffected components can be hidden in the visualization. In this way you can recognize all the problem areas at a glance, even in the most complex models.
Using automatic methods, scFEMod can correct meshes in a few seconds. By clicking pairs of components you can force their meshes apart to a previously defined minimum distance between the linking points. The topology of the mesh remains intact.

Other intelligent algorithms in scFEMod allow you to process other common mesh errors either automatically or manually, such as intensive strain and torsion of meshes. Even very small mesh elements that limit the time step and therefore also the computational speed of the FE solver can be enlarged.

### Advantages

**Less time needed for mesh correction**
The intelligent algorithms in scFEMod allow you to detect and correct mesh errors in a very short time.

**Repeating initial phases of the simulation is no longer required**
Previously, mesh errors could only be reliably identified during the initial simulation phases of the FE model. Using scFEMod you can now recognize problems directly. This shortens the simulation process significantly.

**More accurate results**
Simulation errors caused by undiscovered and unrectified mesh errors are avoided.

**Shorter computing time for the FE solver**
The smallest of the time-step-limiting mesh elements can be found and enlarged.
Easy assembly of components

During the early development phases, the information about the links between the individual components of an FE model is often incorrect or completely missing. When components are replaced by variants, the link information can become invalid so that, for example, spotwelds hang in mid-air. This information can also be missing completely if it is to be specified in detail during a later construction phase. Furthermore, invalid links can be caused by changes in the geometry.

scFEMod can find faulty or missing links and clearly display them. You can correct links manually or automatically and you can create new links. scFEMod handles spotwelds, weld seams and adhesive bonds.

Checking and correction

Special visualization allows you to easily identify and distinguish correct and faulty link elements. Color coding as well as shape is used to make the type of link error identifiable. Common errors are inadmissible angles or distances, spotwelds or weld seams being too close to one another, or spotwelds that are too far away from a flange.

Using sophisticated heuristics, scFEMod can correct faulty links or add missing ones automatically. For example, with a few mouse clicks, missing links for a newly replaced component can be recreated exactly as they were on the component that was replaced. Even quality criteria for links can be checked, such as the distance between components for adhesive bonds, or angles on flanges. If there is an error, scFEMod can automatically correct the geometry.
Creating new links

Intelligent algorithms allow you to recognize missing links and quickly add them.

You can find unlinked components automatically by blending out all previously meshed components. Configurable algorithms for flange recognition enable scFEMod to recognize also individual unlinked flanges and highlight them in the visualization. It's then left to you to decide which of the flanges you want to link.

Links are normally created with scFEMod through automatic methods. You use the mouse to select the part to be linked. You either then let the components be automatically linked or you specify the area in which the components are to be linked. The rest is done by scFEMod automatically. For example, you can specify individual parameters that control how scFEMod handles these settings, such as the required distance between spotwelds, the maximum spacing between components or the allowed distance from flanges. Links can be added directly to flanges or even in the middle of components. scFEMod also has no problem in handling difficult areas such as corrugated or interrupted flanges. You can either use the automatic methods for setting and changing links, or you can do this manually.
scFEMod can even link corrugated flanges automatically.

With just a few mouse clicks you can link a complete flange using weld seams (left) or spotwelds (right).

**Advantages**

**Rapid linking of components**
You can rapidly link different component variants to a model. Areas between components that can be linked, but for which in an early development phase there is no link information, can be identified and automatically linked by scFEMod in a very short time.

**Fewer erroneous calculations**
Links that are faulty or not yet available wouldn’t normally be detected at all or only when the simulation run starts. These can now easily be detected and corrected before the simulation.

**Precise modeling of spotwelds, weld seams and adhesive bonds**
The simulation accuracy increases because more physically valid models can be created in contrast to prior methods that directly connect nodes.
Model completion

During the early development phases, individual components are often not yet modeled and for the purposes of early simulation they need to be substituted. For this, there are two typical scenarios: first, components that are not part of the load-bearing structure, and second, fastening parts between components that have not yet been modeled in detail. For both scenarios scFEMod provides individual solutions.

Components that do not contribute to the load-bearing structure of a model, such as carpets or wiring harnesses, can have their mass taken into account. For a component that has not yet been modeled, scFEMod can add substitute masses that can easily be distributed among neighboring components.

Fastening parts between components that have not yet been modeled can be substituted by rigid bodies. Rigid bodies can be fastened to any nodes of other components. In contrast to welded or adhesive joints, however, the components to be fastened can be far apart. Rigid bodies are defined simply by specifying on the surface of the component to be linked the nodes to which the rigid body is fastened. Additionally, you can assign them a mass.

Advantages

Early concept trials are possible
Simulations can be carried out before all the components and links have been completely modeled.

Rapid linking
Any number of components can be linked without having to share nodes.
Comparison of variants

During the design phase, you want to be able to exchange components of your complete model by variants. This means adapting variants to your computational model and visualizing their effects. As a result, you can recognize where the link data of different variants diverge and where you have to check them. In addition, the visualization should facilitate tracing back variants and variant properties that improved the simulation result.

Using scFEMod's MultiViewer mode, as soon as you have assembled the components you can recognize where a variant differs from the original model. So you can see immediately where you have to check link information. At the same time, you can control unintentional changes to the model. The MultiViewer mode displays the differences between the two geometries in color. These can be two variants of the same component, or the same component before and after you have used scFEMod to change the geometry. In each case, you maintain control over what is simulated.

Simulated variants not only have to be compared with each other but also validated by experimentation. For this you need to be able to compare the simulation results with coordinates, speeds or accelerations that are measured in the experiment by appropriate sensors.

scFEMod allows you to set sensor points that are used for analyzing the data. The coordinates of a sensor can lie directly on the surface or at a specified distance from it. As is the case for real sensors, these sensor points can be assigned a mass that itself influences the simulation.

Advantages

Changes to component variants can be quickly recognized
You know immediately where link data needs to be checked.

Comparison of the simulation with real test data
Using sensor points you can easily compare the simulation results with data from the experiment.
Accelerated work flow

scFEMod was designed to significantly speed up your work flow. This applies not only to the shortened work process but also to working with scFEMod itself.

An intuitive GUI reduces the learning curve considerably. You work with scFEMod mainly using menus, tool bars, dialog bars, and the mouse. Shortcut keys that you can configure yourself speed up the work for advanced users. You can adjust the viewer control and all the mouse and keyboard functions to tailor the interface to the way you want it. In this way you can maintain a high productivity despite frequently switching from one program to another. A macro recorder allows you to record and reuse frequently needed command sequences. At any time, you can store the current work status in the form of projects.

Various display options help you to create a model quickly. Using selective views you can display only certain components, such as those having perforations. Predefined and user-defined views that you can store enable you to quickly take a look at critical areas. You can add notes to these views and store them as graphics files that you can use to communicate information to others who are involved in the project.

Modern parallel processors make it possible to have FE models with millions of nodes. To avoid overloading of the preprocessor, scFEMod uses modern methods of processing large files to reduce memory usage and processing time. Overlapping components are quickly simulated using an 'object-oriented bounding volume hierarchy'. The sc.iViz scene graph layer provides space-saving data storage and fast hardware-controlled graphic output.

Advantages

Time saving
Complex actions can be carried out using a few key strokes and mouse clicks.

Short computer response times even for complex models
The latest visualization technology provides high-performance displays.

High user acceptance
You can tailor the mouse and keyboard functions to your individual taste.
scFEMod is future-oriented

The progress made in FE methods and the increase in computer-processing power will cause FE methods to be employed even earlier and more frequently in the development process. Instead of using simulation only for analysis, it will also be used repeatedly with many variants in early development phases to allow you to make an early decision on the correct concept and to optimize the design.

You can use scFEMod in variant simulations for efficiently replacing, correcting, and verifying components. This can significantly reduce not only the time needed for model preparation but also the number of model errors that can occur in FE simulations. scFEMod, a tool specifically designed for this purpose, does its job highly efficiently. Thanks to scFEMod, a German automobile manufacturer was able to reduce the time required for model processing by two thirds.

scFEMod is not restricted to one particular FE program; it understands a variety of formats. It uses open standards and libraries, which is why it is available on Windows, Linux and many Unix platforms. So scFEMod is a solid investment for the future.

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