

FSI-Visualization with Ceetron 3D Technology

Armin Sager, Ceetron GmbH, Fellbach, Germany

Introduction

MPCCI has, by means of constant refinement, established itself as standard software for coupling simulations in CAE workflows. Its application has definitely broadened beyond coupling major/mainstream solvers to a variety of applications, e.g coupling an established code with very specialized codes. This trend will proliferate because it has become easier to implement support for coupling into solvers and since the understanding of the coupling process has grown in sync with the capabilities and the number of supported applications of MPCCI.

Coupling simulations should sometimes make it easier to simulate a process in a more reliable and satisfying way because either the codes that can be deployed using external coupling fit the nature of the problem better or only the use of coupling allows a proper representation of the physical problem. On the other hand, a coupling simulation often represents a more complex problem, in terms of complexity of the setup and the variety and amount of data generated.

With such complex problems understanding by visualization is more than ever the silver bullet that finally lays any doubts about the significance of the results to rest. This contribution provides an overview over Ceetron 3D visualization technology, how it can complement MPCCI, and present application examples from the collaboration, monitoring and post-processing stages of coupling simulation workflows.

1. Challenges in the coupling simulation workflow

The classical CAE workflow sees more widespread application due to the rapid evolution of computer hardware and software. The simulations now routinely handle models that are one order of magnitude larger than a decade ago and deliver more accurate results in shorter time. The need for a tight integration into the design process has risen significantly as well as the need to communicate results worldwide.

Coupling simulation workflows face the same challenges that stem from these developments. Final and intermediate results need to be communicated outside of the CAE core team using a format that supports 3D-Visualization and Animation in the most common environments, be it e.g. a Linux based system or Microsoft PowerPoint, using viewers that are easy to deploy. Since network bandwidth is typically still a limiting factor, the format utilized needs to store the simulation results as compact as possible.

However, MPCCI based coupling simulation workflows face some additional specific challenges. In the coupling step the definition of coupling regions and exchange quantities currently lack visualization. In complex cases dozens of coupling regions and partitions thereof need to be set up, hence specific preprocessing functionality is desirable.

Once these definitions are specified and the initial iterations have been executed, a visual check of the mapping of the results exchanged via the coupling regions is necessary to assure that the computational effort for a complete simulation is invested properly. The current MPCCI Visualizer offers sufficient support for inspecting 1D and 2D coupling, but its technological basis needs to be enhanced to support inspection of 3D coupling as well as feature extractions like cut planes. Such enhancements should also provide the basis for integrating results and geometries from the solvers involved.

External coupling implies working with multiple solvers, and identifying an adequate postprocessor that allows for combining the results from all the solvers used can be difficult. When MPCCI is used to control the simulations, important information about the results is already available – hence, a tight integration of the postprocessor with MPCCI could use that information to streamline the postprocessing of the results.

2. Ceetron 3D Technology Overview

Ceetron is a software development company offering advanced 3D visualization products and solutions to the CAE market, headquartered in Trondheim, Norway. The company has been in the market since 1995, and provides leading edge technology and know-how.

Ceetron's product line consists of both end-user products and software developer tools. The end-users products are a postprocessor for full 3D visualization and interpretation of CAE models and results (GLview Inova), and free tools for presenting and sharing the essential results– (GLview Express and GLview 3D Plugin). The free tools provide fully interactive 3D animation and the ability to carry the actual result data – thereby allowing for picking of result values.

Equally important are Ceetron's OEM products for 3rd party software developers. The visualization core called "GLview 3D Visualization API" is a powerful, reusable C++ library upon which numerous specialized post-processor and advanced visualization solutions are based – including Ceetron's own postprocessor, GLview Inova. An efficient tool for export of simulation results to the compact GLview Express format (encrypted VTF) is also provided through the "GLview Express Writer" library, which is designed to be very easy to integrate with existing FEM/CFD tools.

Another key segment of the Ceetron activities has always been the development of customized visualization solutions. With the establishment of the German subsidiary in the Stuttgart region, Ceetron makes that specific expertise readily available in Germany.

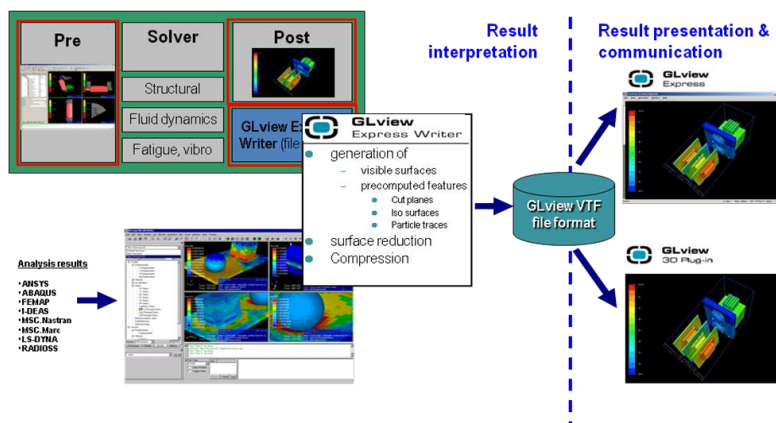


Figure 1: Integration using GLview Express Writer

For more integrated solutions, the GLview Express Writer Library can be accessed directly from the source of the data, e.g. a special solver or, as depicted in this case, a complete custom developed visualization solution developed around a solver. It is then the task of the Express Writer library to generate the VTFx files that can be viewed with the free viewers.

3. 3D-Visualization is essential to sharing of results

“If a picture says more than 1000 words – an interactive 3D animation says it all ...”

The following example from the automotive industry illustrates how lightweight 3D visualization tools in combination with a compact and flexible file format can be used to



Figure 2: Input and output of the forging process

improve the communication in the team and to strengthen the link to downstream stakeholders. The example uses models from a hot metal forging process to create a steel knuckle for the chassis of the Maybach car, starting with a solid block of steel as initial part.

The producer, CDP Bharat Forge, used the forging software Forge by Transvalor to optimize each stage of this multi-stage forming sequence.

As the complete process is planned and analyzed, lightweight files can easily be produced for each stage to enable the team to visualize the models and important results in full 3D with full

interactivity. By giving the whole team access to the same information, correct decisions may be reached faster, and the reasoning for the conclusions will be understood by all members of the team.

The preparation of meetings is more effective, because a single slide with an animated 3D Model communicates more information than several slides with stills or animations with

fixed perspective.

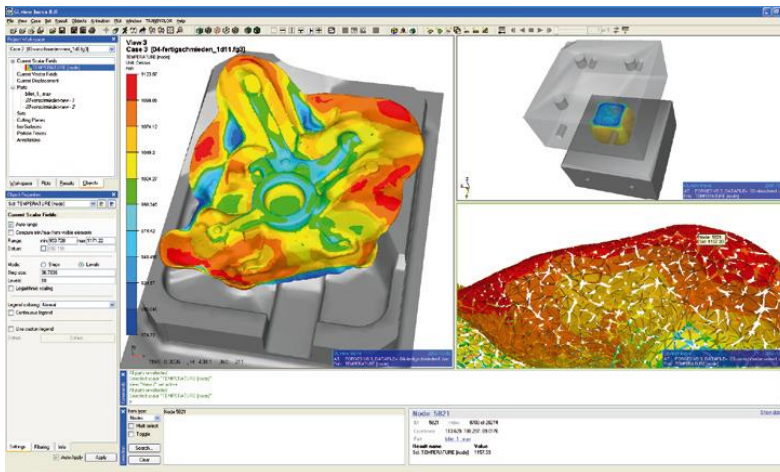


Figure 3: Post processing of stages of the forging process

4. File size reduction techniques

With the size of models increasing, the demand for data storage space is rapidly increasing. And because of the need to collaborate globally, network bandwidth limitations need to be addressed. Both these factors make it necessary to deploy techniques for reducing the size of the files exchanged and stored while retaining the technical information that is required to draw the right conclusions – the team must be able to communicate the essence of the analysis with ease.

For the metal forming example above, file sizes are reduced from 2.7 GB in the original format to 68 MB by:

- Selection of individual results, steps, parts and sets to include
- Removal of interior data
- Export of 1st order nodes only
- GZIP type file compression

This particular real world analysis example shows that substantial file size reductions

can be achieved even if several complex models with adaptable meshes are involved. The resulting files are small enough to be easily distributed – in contrast to the original files. In other common scenarios, even better file size reductions are typical as illustrated in figure 4. Such size reduction offers an additional advantage- It allows for routinely archival of interactive 3D-models for documentation purposes, which can be reviewed within minutes without the need to rerun the simulation itself.

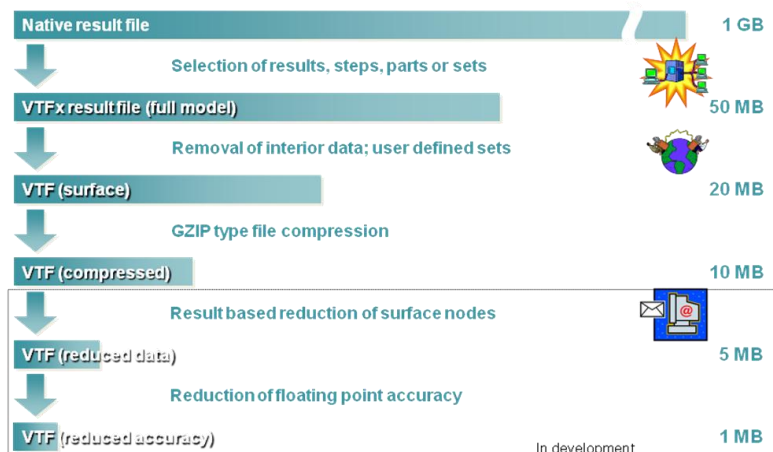


Figure 4: File Size Reduction Techniques

A complete solution for transferring analysis results between locations and organizations over the Internet needs to include password protection, data encryption and support for digital signatures to ensure that the data reaches the recipient in its original form and that only the intended recipient(s) can read it.

6. Coupling Monitoring.

When applying external coupling methods a visualization component is required to visualize the geometry of the coupling regions, the orphaned nodes and exchanged quantities to verify that the setup establishes a successful coupling. This can only be achieved with a dedicated tool because the visualization features and the user interface needs to be optimized for this task, and because it needs to be tightly integrated with the coupling framework.

We have used example trace files provided by the MpCCI team to test coupling visualization with Ceetron 3D visualization technology. As a first step we have extracted the geometry and result data from the HDF format and have created equivalent ASCII VTF files in a manual process. This turned out to be a rather straightforward procedure, since the formats used for the basic geometry and result data are very similar.

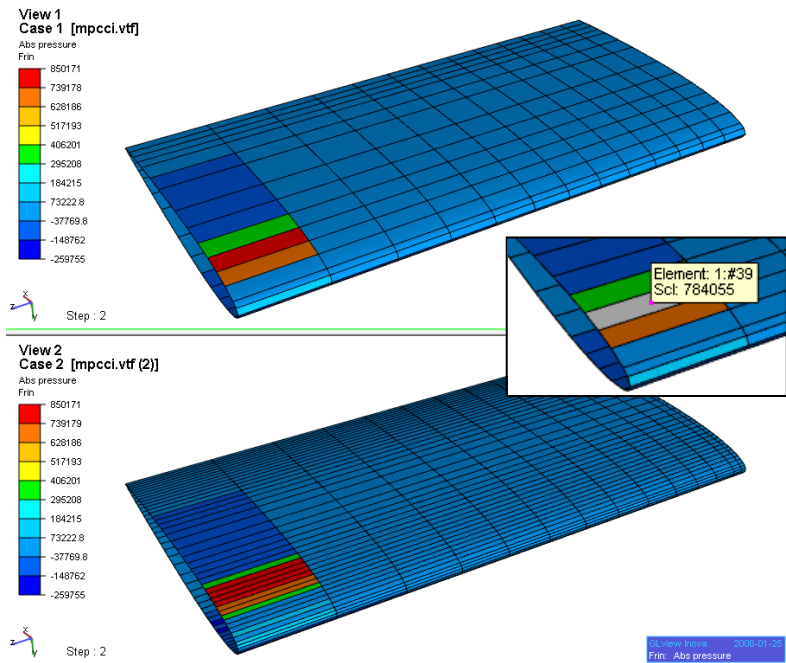
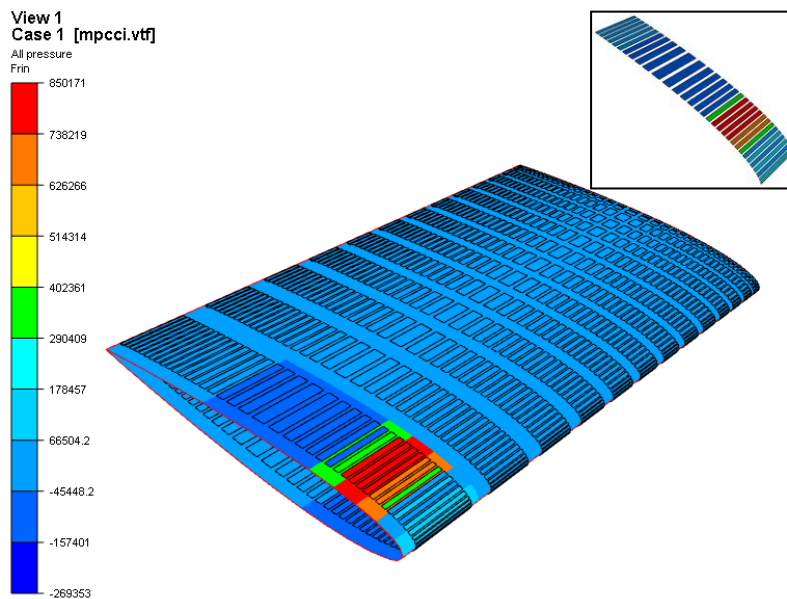


Figure 5 shows the result for the scalar result “Abs pressure” on the surface of a wing, as exchanged to couple Fenfloss (a CFD code) and Abaqus. In this case, Fenfloss is used to calculate the pressure, while Abaqus uses these values as input for simulating the resulting deformations of the wing. The deformations of the wing are then fed back into Fenfloss.

The GLview Inova based visualization presented here uses one viewport per result. Both viewports are synchronized in terms of navigation, legend range and coloring etc.. Obviously the mapping of the pressure data

Figure 5: A coupling region as seen by the codes involved

to the coarser Abaqus mesh is appropriate. Picking nodes or elements is possible for each viewport. The case shown visualizes the input pressure values to Abaqus calculated by Fenfloss and transferred through MpCCI.



Superimposing the Fenfloss model and mesh on the Abaqus model while shrinking the elements of the Fenfloss mesh results in figure 6. This visualization provides a very good method for checking the 2D coupling process since not matching colors in adjacent cells highlight potential irregularities.

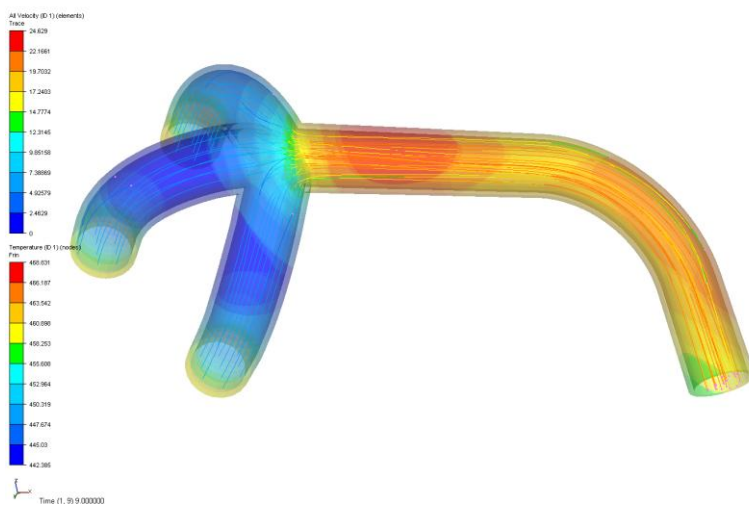
The inset shows the effect of rendering shrunken elements for a subset of the Fenfloss mesh.

Figure 6: Coupling with both meshes superimposed in place

The strong animation features of the Ceetron 3D visualization technology allow using the same options to monitor a coupling simulation as it progresses.

8. FSI Visualization with GLview Inova

For an example that combines CFD simulation results from Fluent and FEM results from Abaqus, we have used the final results of the well known “exhaust manifold” example from the MpCCI tutorial. To produce figure 7 first the “exhaust_manifold.odb” file is imported in GLview Inova. The scalar result “Temperature” is selected to generate a contour plot showing the temperature distribution on the exhaust manifold surface. The manifold part is made transparent.



Now the “exhaust_manifold.cas” file containing the Fluent geometry can be added to the GLview Inova workspace as an additional analysis. Adding the “exhaust_manifold.dat” with the Fluent result data from the final coupling step completes this second import step.

By applying a particle trace box we generate particle traces and map the absolute value of the velocity to the particle traces.

Hiding all parts of the Fluent geometry leaves only the traces visible.

As a final step we combine both views in one single viewport using the superimpose feature of GLview Inova.

Superimposing is used in the very same way to combine the results for the “busbar” MpCCI example (an electrothermal analysis). However, in this case (almost) coincident cutting planes are used - one showing the temperature distribution in the air surrounding the busbar and the other one showing the heat generated in the busbar by the current running through it. The models are then clipped by the cutting planes.

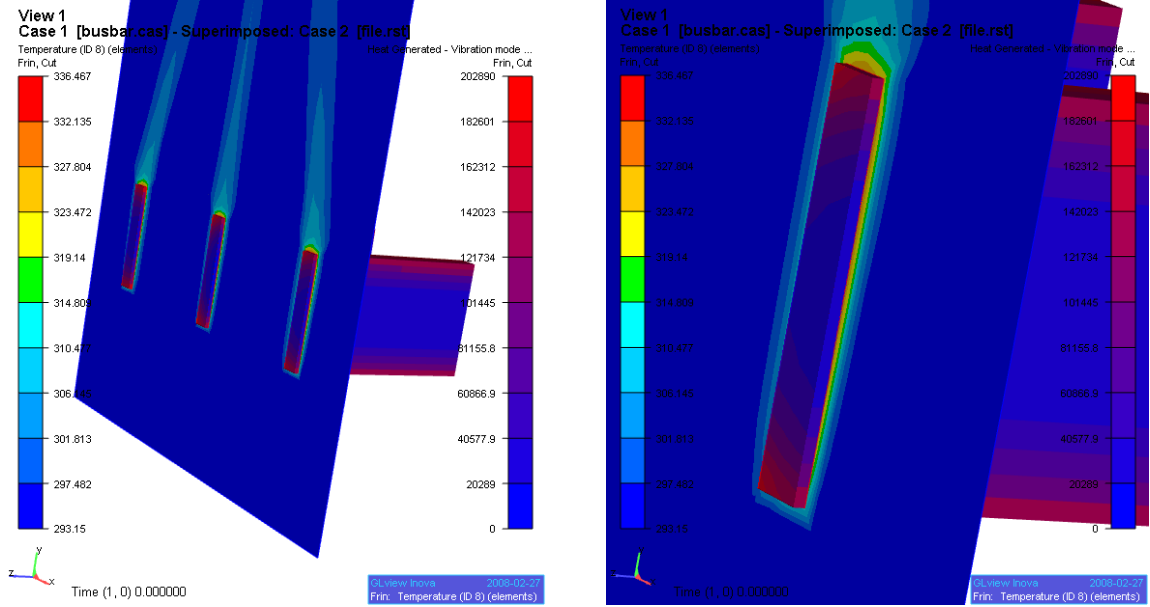


Figure 8: “Busbar”Visualisation

7. Conclusion

The visualization of results from coupling simulations is a complex task. The post-processing of the results requires tools that combine broad support of codes from the FEM and CFD domain via import filters, good rendering performance, high rendering quality and an easy to use support for animations as a basis. It also requires a state of the art feature set that is implemented in a very generic fashion so that the tool shows a high versatility when applied to the very diverse set of result data and visualization tasks encountered in this domain.

Already the visual monitoring of the coupling process needs a tool based on a rich and stable basis technology with features tailored to the task by means of a specifically designed graphical user interface.

Strong support for the presentation and collaboration part of the workflows in which the coupling simulations are embedded is of the same importance as for uncoupled simulations and should be key to further prove the advantage of using coupled simulations when adequately used.

Because of the strong potential benefits we would like to drive the application of our advanced 3D visualization technology and thereby contribute to the evolution of the technology behind externally coupled simulations.