SAVI: SYNCHRONOUS ADVANCED VISUALIZATION FOR SIMULATION RESULTS

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DEEP INSIGHT FOR CHALLENGING PROBLEMS

Finite Element Analysis (FEA) tools are widely used to predict structural responses to mechanical and thermal loads in all types of consumer products, and many excellent commercial packages exist for this purpose. Simply *solving* an FEA problem is the means to the end and not the end goal in itself – an analyst ultimately seeks to extract insight from the mountain of data stored in an FEA solution file to guide the design evolution. The analyst picks up FEA to answer some fundamental question: how much clearance exists in this subsystem once internal pressure is applied?; Where does the peak stress occur when combined structural and thermal loads are applied?

For problems with simple, linear responses, often static images suffice to tell "the story" – the mechanical response to applied loading. All commercial software packages offer a variety of static visualization options, as well as the ability to plot response variables over time.

But for more complex problems – which may contain multiple bodies in intermittent, multi-point contact, solutions which develop over time, multi-staged loading, and large displacements – understanding what happened during a simulation may become suddenly much more challenging. Clearly conveying "the story" to members of the team who have not pored over FEA results may be even harder!

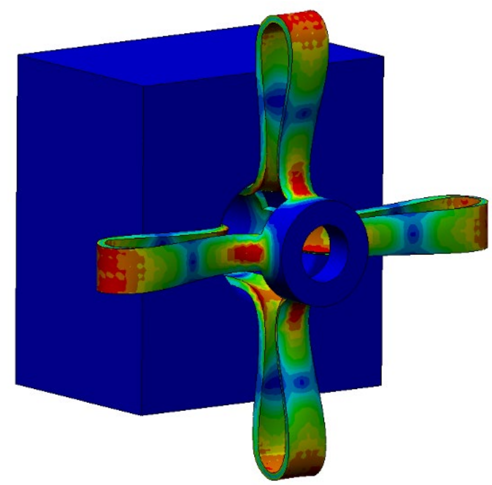

Figure 1: Static visualization of an FEA result. Stresses are visualized by plotting a colormap over the shape of a deformed part (hot = high stress, cool = low stress!)

At FPrin we understand the explicative power of advanced visualizations in these situations. We have developed **S**ynchronous **A**dvanced **Vi**sualization (**SAVI**) software which combines multiple time dependent FEA outputs to create highly customizable multi-pane animations and extract deep insight from challenging simulations.

Our approach, which produces visualizations that are not possible in any commercial FEA platform that we are aware of, leverages the strengths of commercial FEA packages for visualizing deformations and contour plots, as well as the extensive 1D data plotting tools available in the high-level computing platform *Matlab©*. Our tool creates time-synchronous visualizations showing critical results from multiple viewing angles simultaneously, or showing the evolution of a key solution variable side-by-side with an animation. Our code is stand-alone, can accept result files from all major FEA platforms, and can be configured to present any combination of results we desire.

Let us look at a case study where this visualization proves especially valuable!

CASE STUDY: DRYWALL ANCHOR

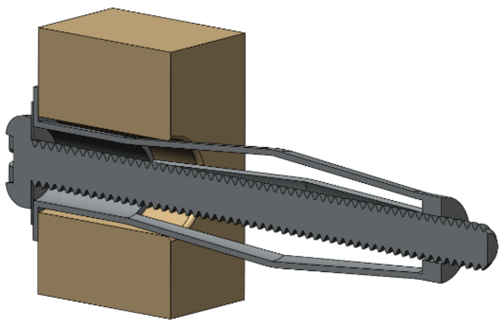

Figure 2 - Drywall anchor before deployment (section view)

We demonstrate the usefulness of our approach with a simple example: the installation of a drywall anchor into an oversized hole, and its subsequent forced removal. We have used an unmodified, freely available solid model (McMastercarr© PN 97102A517) for this analysis, and performed our simulation using Solidworks© Simulation (Dassault Systèmes).

In actual use, this drywall anchor is tapped into a snug through-hole and deployed by rotating a captive screw which buckles a slotted metal sleeve outward. After fully tightening the anchor, the sleeve is pulled closely against the back side of the drywall and provides a mechanically interlocked point of attachment on the opposite side.

Our simulation models a contrived case where the through-hole is oversized and does not properly fit the anchor. We simulate the deployment of the anchor by prescribing relative axial displacement to the end of the slotted metal sleeve, which causes the sleeve walls to buckle outwards dramatically. We then draw the anchor back out of the drywall, severely distorting and folding the buckled portions of the sleeve and pulling the anchor through the installation hole.

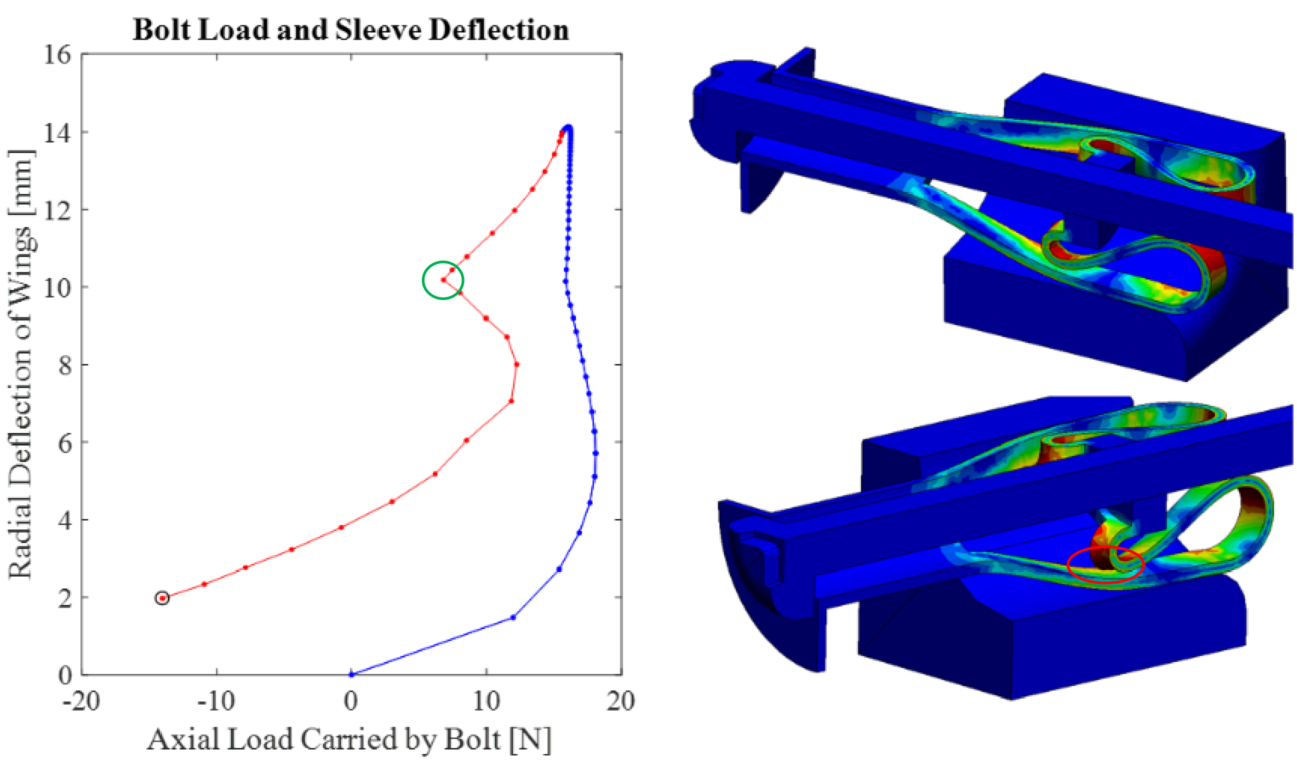

Figure 3 - Still frame from custom visualization. Phase portrait of response variables plotted at left (blue indicates deployment of anchor, red indicates removal; tension is positive, and compression is negative), time-synchronous animation of anchor failure is shown from two angles at right. Visualizations are shown in quarter symmetry, displacements are shown true scale, contour color overlay indicates level of Von Mises stress

Though the scenario we are simulating in this case study seems mundane and the parts are geometrically simple, the mechanical response of this case study is quite complex. At FPrin we analyze systems with greater geometric complexity and ask the same questions we will ask here: How can we visualize the results of this simulation effectively? What might some important response variables be and how are they related to each other? How does intermittent contact change load paths throughout the assembly?

For this case study, suppose we care about the axial load carried by the bolt throughout the simulation, and the radial expansion of the anchor sleeves. Our visualization software creates a custom multi-pane animation showing these variables, along with two viewpoints of the anchor deformation. Any single one of these panes is insufficient to understand the full response modeled in the simulation. Taken together, we can cross reference them and identify the contact interactions and displacements that give rise to various features in the phase portrait.

For example, the sharp discontinuity circled in green occurs when the outer sleeve folds back on itself and contacts the shaft of the screw. Additionally, a counter-intuitive reversal of bolt load occurs partway through the anchor removal (the load shifts from axial tension to axial compression). By cross-referencing with the animations, we see that this coincides with the point of self-contact in the buckled outer sleeve passing over the contact point with the ID of the installation hole (region circled in red). After this point, the "S" shape of the sleeve imparts a force to the distal end of the anchor in the direction of removal, resulting in an unexpected compressive bolt load.