Demystifying Optimization in Simulation  
Shekar Sub, Peter Maxfield, Jeff Higgins – Autodesk Inc

SM6326: Meaningful CAE analysis includes adopting Optimization in the simulation process. We will present the Past, Present and Future of Optimization for Simulation.

In recent years, Autodesk made inroads into optimization on the cloud with Inventor Simulation. Current offerings, including Simulation Mechanical, CFD, and Moldflow, which provide state of the art techniques including parallel solving and Design of Experiments.

Sim360 provided parametric optimization on the cloud. A new unified simulation platform is being developed called SimStudio Platform which supports Topology Optimization.

Learning Objectives

At the end of this class, you will be able to:

- Learn about Optimization in products like Inventor Simulation, Simulation Mechanical, CFD, and Sim360
- Perform Design Of Experiments with Moldflow
- Learn about the upcoming cutting-edge tools like topology optimization in SimStudio Platform

About the Speaker

Shekar Subrahmanyam is the technical leader for Autodesk SimStudio and Platform initiative. He has worked on Sim360 and Inventor Simulation. He is one of the authors of the book, Mastering Inventor 2009 and LT 2009. His educational background includes a bachelor’s, a master’s, and a doctorate degree in mechanical engineering. He completed the Advanced Certificate for Executives in Management, Innovation, and Technology program at the Massachusetts Institute of Technology Sloan School of Management. Shekar teaches classes at Autodesk University, and he volunteers for the Autodesk Idea Connection and the Destination Imagination program for kids.

Peter Maxfield is a Principal User Experience Designer for the Digital Simulation team. He has over 18 years’ experience as a UX designer, 12 of which with Autodesk working on Inventor and the Simulation products. His recent work has focused on adopting cloud technologies to the Simulation product suite, as well as bringing simulation technologies into design-focused arenas for more immediate impact. Peter holds a BS in Mechanical Engineering from Cornell University.

Jeff Higgins has been with Autodesk since the acquisition of Moldflow in 2008. As the Named Accounts Technical Specialist for the Named Accounts Team, Jeff’s duties include helping major accounts grow simulation business within their accounts and working with Simulation Major Accounts overlays to increase Simulation activities. Prior to joining Autodesk, Jeff was with Moldflow for 12 years, and worked as an application engineer to the Automotive Industry. During that time, Jeff worked to build confidence in simulation with Automotive OEM’s and Tier level suppliers to implement Moldflow, and certify users.
with Moldflow software. Prior to joining Moldflow, Jeff was a process engineer at Adams Manufacturing. Jeff was responsible for processing and maintaining manufacturing on a 35 press manufacturing facility.

Future

Autodesk SimStudio Platform is the next generation unified platform for simulation. Its key features are:

- Built on the Fusion platform
- Built on a Robust Geometric modeler i.e. Autodesk Shape Manager
- Designed with Optimization Built-in
- Intuitive Multiphysics
- Cloud Connected
- Automation Tools

1.1 What is Parametric Optimization?

In parametric design there is a question about what is the optimal set of parameters the design needs to have to meet the performance targets. If I have a few parameters I can try simulating them individually, however real-world examples could run into hundreds of iterations. Given a set of goals and constraints, vary parameters to find the variation/s that meets a set of performance targets. This is also known as size or shape optimization. In Sim360 users can change the shell thickness to find the optimal thickness for a given set of loads and constraints. This is optimizing an attribute which will not change the actual geometry, however the changed shell thickness is used to find contacts and generate simulation results.

1.2 How do I perform a Parametric Optimization

Parametric optimization can be performed using the following inputs:

- Goal: Minimize displacement, deflection. Maximize Safety Factor
- Constraint: Safety Factor > 2
- Parameters to vary
  - Extrusion distance
  - Number of ribs
  - Materials
  - Shell Thickness

Solve, Optimize command is used to do the parametric optimization solve.

1.3 Parametric Optimization results

Since optimization analysis involve many runs aka, simulation solves, it is imperative that there are good charting capabilities to analyze the results. Most notable among them are pareto plots, named after the economist Vilfredo Pareto. Pareto plots provide an visual means to analyze trade-offs between often competing goals. Each point on the Pareto plot represents a simulation solve or a design alternative. The pareto plots are enhanced with graphical design alternatives to aid in the selection of
viable designs. While the plot suggests the ideal solution, it needs to be balanced with the manufacturability and other constraints. Sensitivity, Progress, Scatter and Parallel Coordinate plots are other examples to visualize the vast amounts of data generated in an optimization. With parallel coordinates its easy to see the lines that passes through the run(each simulation solve) number, goal and parameter values of the simulation solve that is selected for further analysis.

2.1 What is Topology Optimization?

In concept design often there is a need to define a rough shape to meet some performance targets. Computer-Aided Design (CAD) should aid in the generation of a design. However CAD has mostly helped with tools to transcribe a design into the computer. Topology Optimization is the right step to aid users in generating a design. Given a set of goals and constraints topology optimization finds the optimal mass distribution in a model that meets a set of performance targets. It is a mesh-based approach classifying the mesh elements as “keep” or “remove”. The optimization analysis is performed using the world-class Autodesk Nastran Solver which uses the Solid Isotropic Material Penalization (SIMP) with sensitivity filter method.

Figure 1a: Cantilever (Red = keep)  
Figure 1b: TO analysis done (Blue: Remove)  
Figure 1c: TO results

Figure 1a-1c shows the steps for TO on a cantilever beam. Figure 1b shows the results of a TO with blue regions inside the cantilever to be removed and red regions to be kept with everything in-between(kept) representing the gradation in colors. Figure 1c shows the final optimized result for a specific mass target ratio. The hole in the middle of the cantilever in Figure 1a is preserved in Figure 1c.

<table>
<thead>
<tr>
<th>Design Stage</th>
<th>Topology Optimization</th>
<th>Parametric Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>Concept</td>
<td>Parametric</td>
</tr>
<tr>
<td>Analysis &amp; Solving</td>
<td>Mesh/Solid</td>
<td>Solid</td>
</tr>
<tr>
<td>Technology</td>
<td>Autodesk Nastran Solver</td>
<td>Autodesk cloud-based optimization</td>
</tr>
</tbody>
</table>

Table 1: Comparison between Topology and Parametric Optimization

2.2 How do I perform a Topology Optimization?

The Common Inputs to a simulation consists of the following:

- Geometry
- Loads
2.3 Settings, Goal (Figure 2):

Minimize compliance (mass target for now). In the future we plan to add more goals like displacement, stress, frequency, etc.

- Settings:
  - Solver Selection: Quadrilateral tetrahedral is recommended.
  - Iteration Tolerance (0.005): Used to control convergence tolerance. This aids in solving the problem in a reasonable time. Stop the optimization if density change is less than this tolerance.

- Goal: Mass Target(30%): The target mass percentage in the model after the optimization
Preserve Boundary: Do not optimize away these regions. An easy-to-use Preserve Boundary command can be used to specify the regions. Users can specify the following preserve regions, Box, Cylinder, Sphere. Regions of the model where simulation loads and constraints are applied are automatically kept. Drag manipulators provide powerful ease of use to position and size the primitives. Any mesh node within this preserve boundary will be always kept.

2.5 Topology Optimization Solving

A separate Solve command, Solve, Optimize Topology is used for finding the optimal topology. After the solve, results can be analyzed in the results environment. Though a linear solve is performed as of now, we are looking into consider non-linear solves in the future.

3.1 Topology Optimization: Results

Figure 5a shows the original model. After setting a mass target ratio of 50% you get blue regions (remove) which are removed. Figure 5c shows the kept regions in the model.
Figure 6: Slider control

A slider control (Figure 6) in the results environment aids in controlling the number of mesh elements that are “in” or “out”. For a 0.5 value the TO results are considered to be precise and accurate. For any other position of the slider, it’s not an accurate representation of the mass ratio or approximate mass.

3.2 Nastran capabilities

The use of Nastran technology supports all load and constraint types including NASTRAN subcase for multiple load and constraint cases. Linear contact, Bolt preload, composite elements and other element types and features are supported. For design regions all shell and solid element types are supported while all element types are supported for non-design regions. In a design region, the mesh elements can be removed to satisfy the mass target, while in a non-design region, the mesh elements are preserved due to constraints. Detailed status information gives progress of solution for each optimization iteration.