Topological Optimization Case Histories at GE Healthcare

Doug Grant, Senior Mechanical Engineer
Imaging Technology Hardware
GE Healthcare Overview

• $19B revenue, 50,000 employees worldwide

• Products = Diagnostic & manufacturing equipment for the medical provider industry
  ✓ Imaging - MRI, CT, X-Ray, Nuclear Medicine
  ✓ Anesthesia Delivery & Ventilators
  ✓ Ultrasound
  ✓ Patient Monitoring
  ✓ Infant Care
  ✓ Life Sciences - Biomanufacturing Equipment

• Primary simulation toolset = ANSYS
Why Optimize?

• **Weight = Cost**
  - Material
  - Machining
  - Shipping/Handling
  - Ancillary effects - larger drive systems, etc.

• **Customer Impacts**
  - Room size, floor strength
  - Workflow obstacles

• **Time to Market**
  - Optimization = get it right the first time
  - “More inspiration, less perspiration”
Topological Optimization at GE Healthcare (GEHC)

History & Current State

- March 2014 - Demonstration optimizations using GTAM performed on Portable Ultrasound base by Vanderplaats R&D (Hong Dong)
- September 2014 - Purchased (3) globally shareable GTAM licenses, have re-purchased every year
  - ANSYS Workbench plug-in = major selling point
- GTAM has been used by a few GEHC business unit engineers, more frequently is applied by corporate central team as an engineering service
1st Optimization Success – “The Convincer”

- Design Project = Integrated MR “Body Coil” and Patient Support

➢ Design Objective = Integrated patient support with minimal material that satisfies body coil deflection criteria
Initial Evaluations using Conventional FEA

Proposed Support Design 1

- Solid – 19.1 kg
- Acceptable Deflection

Proposed Support Design 2

- Hollow – 5.8 kg
- Unacceptable Deflection
Topological Optimization Solution using GTAM

<table>
<thead>
<tr>
<th>Design</th>
<th>d, mm</th>
<th>Mass, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>-0.27</td>
<td>19.1</td>
</tr>
<tr>
<td>Hollow</td>
<td>-0.61</td>
<td>5.8</td>
</tr>
<tr>
<td>Modified Hollow</td>
<td>-0.28</td>
<td>9.0</td>
</tr>
</tbody>
</table>

- Design based on optimization gives same performance as fully solid design with >50% mass reduction

Conventional FEA
Optimization of a Multi-Configuration Structure

- Design Objective = Reduce mass of robotic C-arm X-Ray detector lift mechanism
- Primary load = self-weight
- Optimization challenge = mechanism and support structure can assume numerous positions and orientations

Detector can be randomly positioned vertically
Optimization of a Multi-Configuration Structure

Simulation Methodology

• Use conventional FEA to determine
  ✓ Worst case C-Arm orientation
  ✓ Reaction forces imposed on lift mechanism for a series of detector positions

• Use reaction forces as multiple load cases in GENESIS optimization solutions

Load Case 1

Load Case 2

Load Case 3

Load Case 4

X-Ray Detector Lift Frame to be optimized
Optimization of a Multi-Configuration Structure

- 40% mass reduction
- CTQs
  - Stress
  - Deflection
  - Modal Frequency
CT Upgrade Structural Design via Topological Optimization

- Design Challenge = Increase 1st natural frequency of stationary CT support structure by 2x to prevent vibration-induced image distortion

  - Initial Design Approach = trial & error DOE via conventional FEA
CT Upgrade Structural Design via Topological Optimization

- Design Iterations:

1. 9.4 Hz
2. 10.0 Hz
3. 10.2 Hz
4. 10.4 Hz
5. 11.5 Hz
6. 12.5 Hz
7. 11.9 Hz
8. 11.7 Hz
9. 11.5 Hz
10. 12.5 Hz
11. 12.7 Hz
12. 12.8 Hz
13. 16.0 Hz

➢ After 13 iterations (2 engineer-weeks), 18 Hz target natural frequency still not reached
CT Upgrade Structural Design via Topological Optimization

Design Space

Optimized Shape
Constraint = 1st Modal Frequency
Objective = Minimum Mass Fraction

Final Design
Meets Requirements
Thermal Optimization for Circuit Board Heat Sink Design

- **Design Challenge** = keeping circuit board components below maximum allowable temperatures via passive heat rejection (conduction and natural convection)
  - Circuit board is enclosed in airtight housing to shield from EMI emitted by Magnetic Resonance electromagnets and RF generators
  - Typical heat rejection solution = uncooled aluminum plate + thermally conductive padding mounted below circuit board

- **Topology Challenge** = determine optimal shape of heat sink plate that enables all electrical components to operate below their maximum allowable temperatures
  - Full coverage plate = heavy, expensive, potentially not feasible due to interferences with cables, connectors, etc.
Thermal Optimization for Circuit Board Heat Sink Design

Methodology and GTAM Setup

• Design Space (Topology Region) = full coverage aluminum plate and thermal pad (size = 400mm x 400 mm)
  - Plate and Pad modeled with 5 mm linear tetrahedral elements
• Manufacturing Constraint = “Z” (through thickness) extrusion
• Minimum Member Size = 100mm
• Objective = Minimum Mass Fraction
• Constraints = Maximum Allowable Temperature for each electrical component (66 total)
  - Geometry = corners of components’ top surface to reduce design cycle solve time
Thermal Optimization for Circuit Board Heat Sink Design

• Results - 1st Optimization

Topology Isosurfaces #1
Visualization Slider = 0.30

Verification Model #1
(Used for Optimization Run #2)
Thermal Optimization for Circuit Board Heat Sink Design

- Results - 2nd Optimization

Topology Isosurfaces #2
Additional Material Can Be Removed (Shown in Blue)

Verification Model #2
Temperatures in optimized design have increased, but are still below their allowable levels.

Component Temperatures – Full Coverage Heat Sink

Component Temperatures – Optimized Heat sink #2
Conclusions

• Optimal heat sink shapes can successfully be developed via thermal topological optimization
• Verification shapes based on 30% retained material appear to match optimization results well
• Topology results are significantly affected by minimum member size, should perform parametric studies to select optimum value
• Definition of temperature constraints drives tradeoffs between fidelity and solve time
• Next step = design and verify practical heat sink shapes