Topology Optimization of Racecar Suspension Uprights

Billy Wight
Luxon Engineering
Altair HyperWorks Technology Conference
June 23, 2011
Orlando, Florida
Company Profile

- San Diego Based Engineering Consulting Firm
  - Product Development
  - Mechanical Design and Analysis
  - Finite Element Analysis/Optimization
  - CAD Modeling and Manufacturing Drawings

- Located in San Diego, California
- Small Company, 3 Engineers on Staff
- In Business Since January, 2007
- Wide Variety of Industries Served
  - Industrial Equipment
  - Medical Device
  - Consumer Products
  - Automotive
Application Profile

D Sports Racer (DSR) Class
- Closed Wheel
- Modified 1000cc Motorcycle Engine
- 900 lbs Minimum Weight
- 165 mph Max Speed
- ~ 2000 lbs Downforce @ 165 mph
- 2.8 g’s Lateral Acceleration
- Base Price $59,900 (Roller, No Engine)

F1000 (Formula B) Class
- Open Wheel
- Stock 1000cc Motorcycle Engine
- 1000 lbs Minimum Weight
- 155 mph Max Speed
- ~ 1200 lbs Downforce @ 155 mph
- 2.4 g’s Lateral Acceleration
- Base Price $39,900 (Roller, No Engine)
Previous Application Project

Modified Salisbury Differential

- Collaborative Effort Between Luxon Engineering and Williams Racing Developments (WRD)
- Chain Drive from 1000cc Motorcycle Engine
- Direct Replacement for Stohr Cars
  - Fits Other Manufacturers
    - Speeds, Phoenix, Radical, etc.
- Substantial Weight Savings and Performance Benefits vs. Stock
Design Challenge: Suspension Uprights

Stock Stohr Uprights (Current Design)

- Simple, Inexpensive
- Multi-Piece (Bolt-on Brackets)
- Designed to “Get the Job Done” at an Inexpensive Price Point
  - Necessary to Maintain a Reasonable Price for the Base Car
Design Goals and Constraints

Performance Goals:
- Light Weight - Minimize Unsprung Mass
- High Stiffness - Minimize Compliance
  - Suspension Compliance = $f(Springs, Dampers)$
- One Piece Design – Remove Failure Modes

Design Constraints:
- 6061-T6 Material
  - Readily Available
  - Low Cost
  - Good Strength to Weight Ratio
- 3-Axis CNC Manufacturing
  - Readily Available
  - Reasonably Priced
- Keep Stresses Low, ≤ 160 MPa for Main Loadcases

What is the most efficient method of achieving our goals subject to the design constraints?
Altair Analysis Solutions

Meet Design Goals Satisfying Constraints
- Minimize Design Iterations
  - Decrease CAD Modeling Time
  - Decrease Analysis Setup Time
- Engineering Time = $$$
- Decrease Product Development Time
  - Introduce Product to Market ASAP

16 Different Loadcases
- 5 Main Loadcases
  - Typical Racing Environment
- 11 Additional Loadcases
  - Bump Loading, Off Track Loading, etc.
- Derived from:
  - Vehicle Datalog Measurements
  - Suspension Kinematics
  - Tyre Data
  - Aerodynamic Data

TOPOLOGY OPTIMIZATION

- Supports Multiple Loadcases
- One Analysis Run Reveals Optimum Load-Paths
  - Stress Constraint
  - Manufacturing Constraints
Loadcase Development

- Accurate and Complete Loadcases are of Vital Importance
- Optimization Algorithm Can Only Optimize to the Inputs it is Given

- Vehicle Data Logging
  - Allows for Accurate Loadcase Determinations
  - Verification of Calculations and Assumptions

- Extensive/Thorough Calculations
  - Account for All Possible Load Conditions
  - Thermal Effects, etc.
Topology Optimization: Parameters, Front

3- Axis CNC Manufacturing

Split (Both Sides) Draw Direction Constraint
• Ensures No Undercutting in the Result

Multiple Loadcases

Stress Constraint, 100 MPa
• Weights Each Loadcase Equally
• Maintains Target Stress Levels

Minimize Unsprung Weight

Optimization Goal: Minimize Mass
Topology Optimization: Solution Sequence, Front

- **TET4 Design Space (Yellow)**
  - “Material that CAN be there”

- **Topology Result**
  - “Material that NEEDS to be there”

- **TET10 Analysis Model**
- **CAD Interpretation**
- **Final Design**
Topography Optimization: Parameters, Rear

3- Axis CNC Manufacturing

Split (Both Sides) Draw Direction Constraint
• Ensures No Undercutting in the Result

Decrease Cost

Symmetry Constraint
• Ensures Symmetry in the Result
• Rear Uprights are the Same Part Left/Right

Multiple Loadcases

Stress Constraint, 100 MPa
• Weights Each Loadcase Equally
• Maintains Target Stress Levels

Minimize Unsprung Weight

Optimization Goal: Minimize Mass
Topology Optimization: Solution Sequence, Rear

- **TET4 Design Space (Yellow)**
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Iterate
Performance Results

Mass – Decrease of 40%
  • ~ 1.5 lbs per wheel

Stiffness – Increase of 225%
  • Measured via Deformation of a Node at the Tyre Contact Patch

Stress – Goals Achieved
  • Stress < 160 MPa (Main Loadcases)
  • Stress < 220 MPa (All Loadcases)
Conclusions

Engineering Time = $$$

• Optimization Eliminates the Multiple Iterations of Traditional FEA
  • Typical Problems Would Have Taken 15+ Iterations

• The Optimized Design is Often Non-Intuitive
  • Unlikely that Traditional Techniques Would Yield the Same Result

Altair Optistruct Substantially Reduces Engineering Overhead and Development Time
Questions, Comments?

J.R. Osborne, 2008 SCCA DSR and CSR National Champion

Billy Wight
President
Luxon Engineering
(858) 586-1100
billy@luxonengineering.com
www.luxonengineering.com