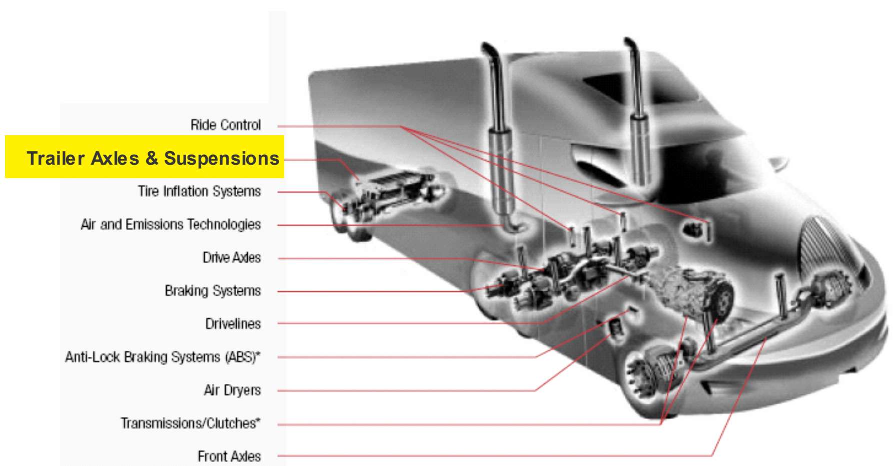
Optistruct Case Studies
OTC 2004

September 23rd 2004

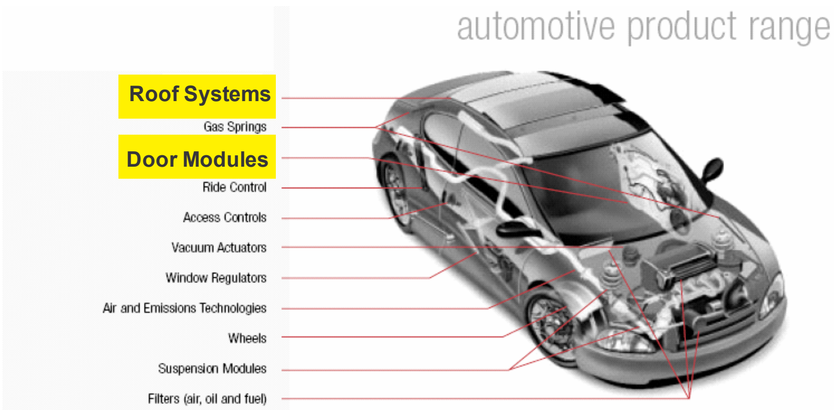
Optimization Technology Conference

ArvinMeritor

Commercial Vehicle Systems
Annual Sales $2.4 Billion



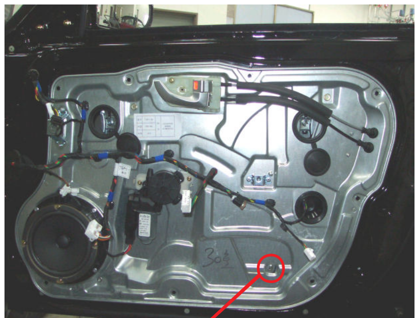
Light Vehicle Systems
Annual Sales: $4.3 Billion



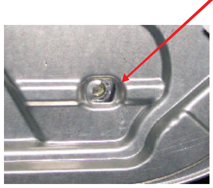
Overview of Case Studies

- Door Module Durability
  Topography optimization
- Wind-deflector Arm for Sunroof Mechanism
  Topology and *shape* optimization
- Trailer Suspension Upper Control Arm
  Topology optimization

Door Module Slam Durability

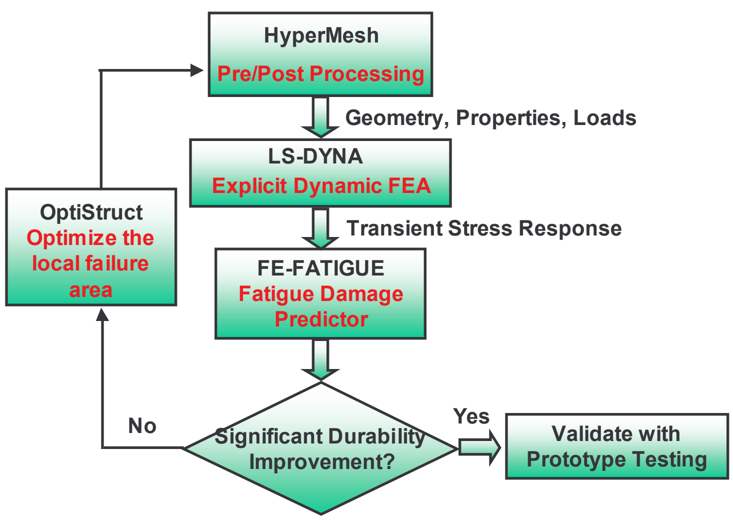


- Door Modules allow pre-assembly of window regulators, latches, speakers, etc. Compared to traditional designs, modules reduce OEM's installation efforts.
- Modules must withstand repeated door slams. Prototypes of this module cracked near a riveted joint very early in slam testing.

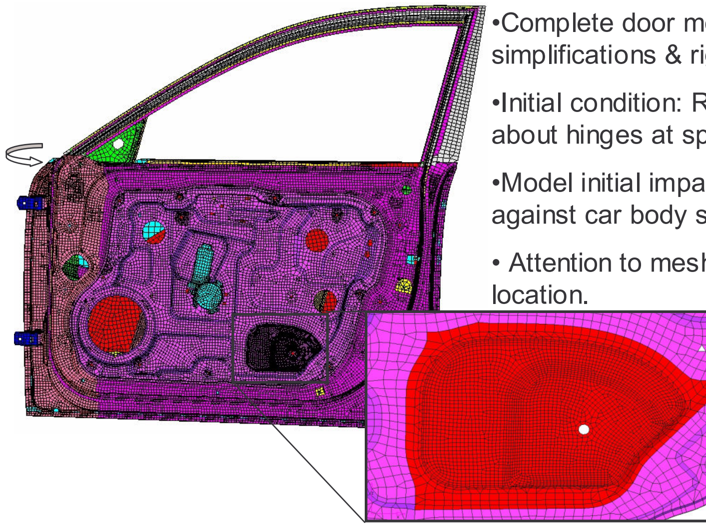


- Collaborative effort required from Product engineers and CAE specialists to improve durability. Intuitive modifications were screened through CAE. Optimization suggested other useful modifications. Significantly reduced prototyping.

CAE Durability Analysis



Slam Simulation with Explicit FEA



- Complete door modeled with many simplifications & rigid connections.
- Initial condition: Rigid body rotation about hinges at specified velocity.
- Model initial impact and rebound against car body seals & striker.
- Attention to mesh near critical location.

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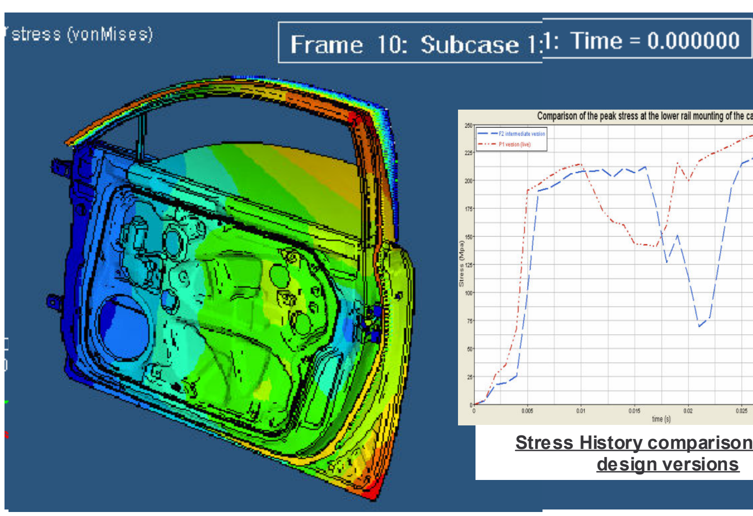
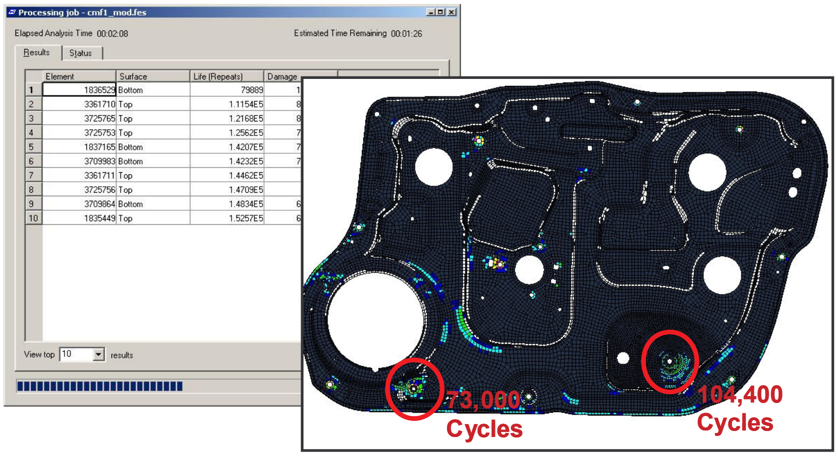
Door Slam Simulation Results



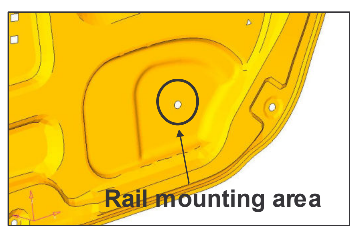
Stress History comparison for two design versions

Door Slam Life Prediction



Initial Modifications

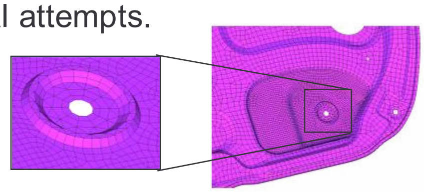
- Intuitive ideas included widening the surrounding mounting area.



- With this change, the CAE Durability Analysis predicted **40,000 cycle** improvement.
- Next prototype included this change and confirmed a 32000 cycle improvement…But….
- It still cracked well below target life !

Topography Optimization of Door Module

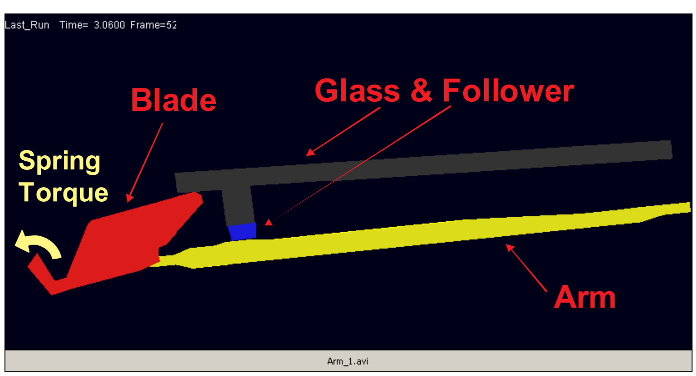
- Substitute a representative static load case.
- Objective was to minimize Displacement.
- Several inconclusive initial attempts.
- Using "Circular Pattern" grouping gave definite results



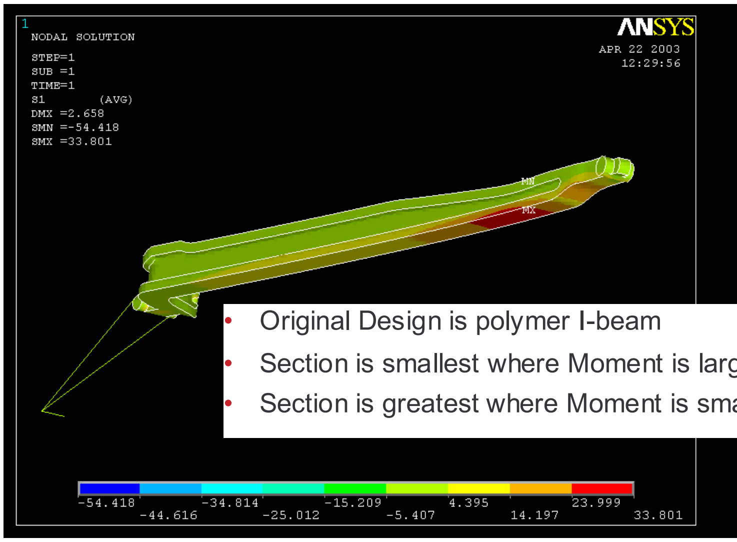
- Circular Rib was analyzed with the full CAE Durability procedure--Showed 41% life increase.
- Next prototype included circular rib and met durability targets.

Sunroof Wind-deflector Arm

- Deflector Blade pops up as glass slides open.
- Blade's range of motion is controlled by arms (1 per side).
- Load magnitude and point of application changes.



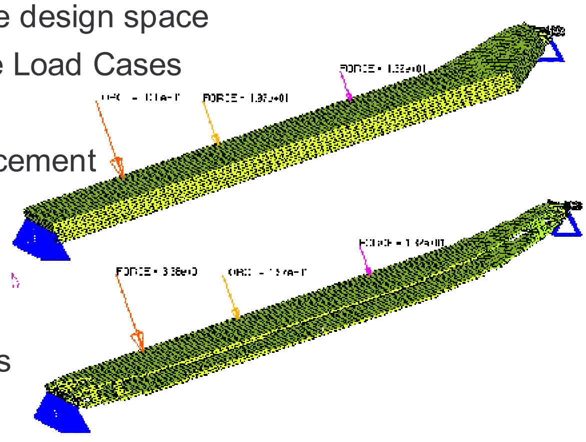
Initial Multi-step Static Stress Analysis



- Original Design is polymer I-beam
- Section is smallest where Moment is large.
- Section is greatest where Moment is small.

Topology Optimization of Wind-deflector Arm

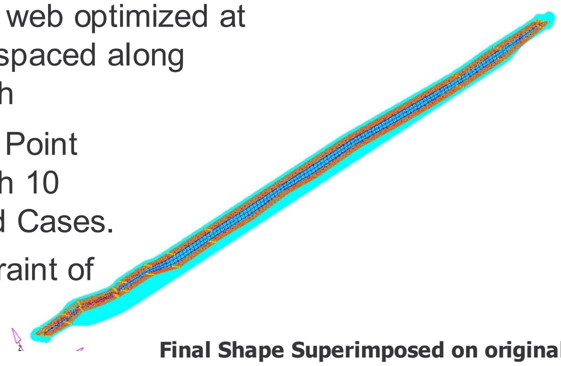
- Mesh all available design space
- Consider Multiple Load Cases
- Minimize Volume
- Constrain Displacement



- Density Plot confirms I-Beam is good choice!

Shape Optimization of Wind-deflector Arm

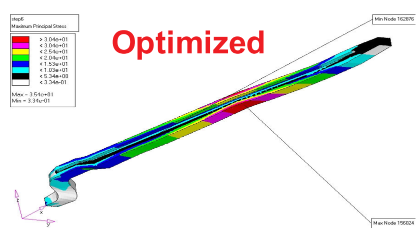
- 2-D shells used to approximate I-beam cross section.
- Height of the web optimized at 11 locations spaced along beam's length
- Moving Load Point simulated with 10 different Load Cases.
- Stress Constraint of 30 MPa

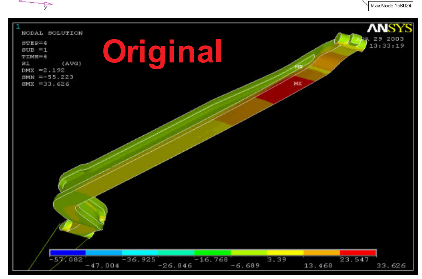


Final Shape Superimposed on original

Before & After Comparison

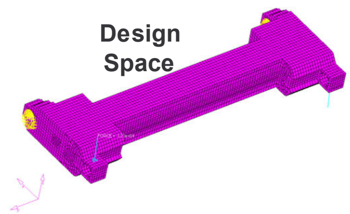
- Optimized Shell element model was reconstructed and re-analyzed with 3D elements. Max Stress = 35.4 MPa
- Max. stress for original design = 33.6 MPa
- Volume reduced 30%, stress increased 5%.



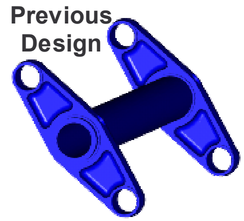


Trailer Suspension Upper Control Arm

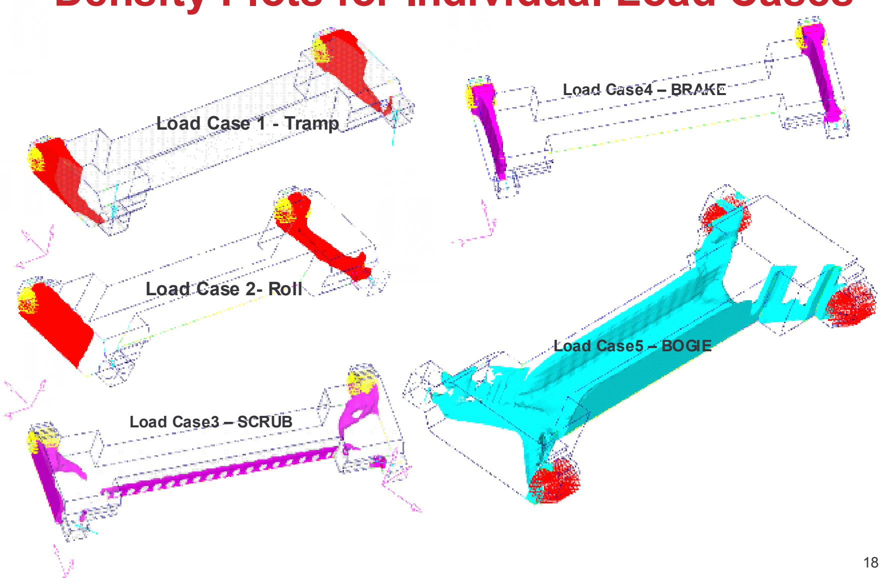
- Topology Optimized for 5 load cases.
  - Responses: Compliance, Mass fraction, displacement
  - Constraints: Mass fraction, displacement
  - Objective: Minimize compliance



- Further constrained by Manufacturing Issues:
  - Simple Shapes
  - Prefer castings
  - Limited welding

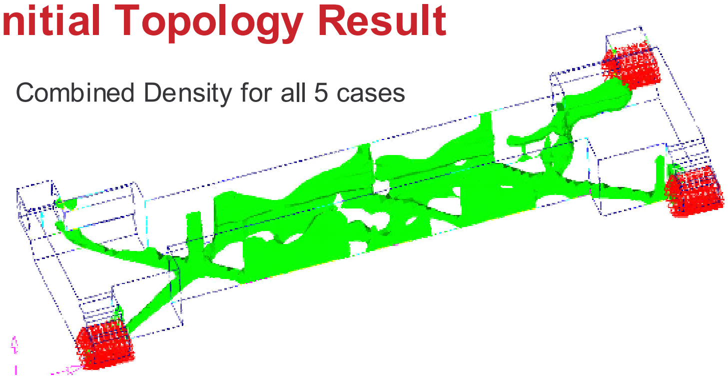


Density Plots for Individual Load Cases



Initial Topology Result

Combined Density for all 5 cases



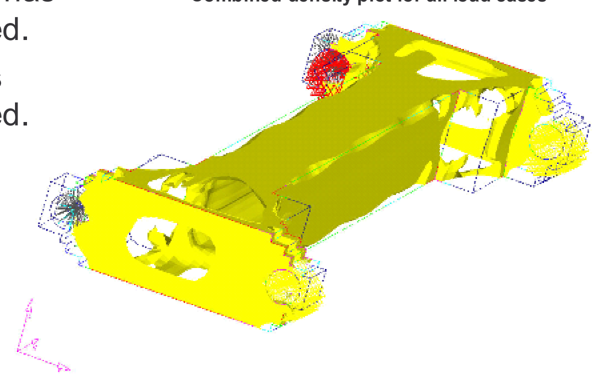
- Practical implementation of the optimized topology result proved challenging.
- Decision was made to add more displacement constraints derived from the original design.

Final Topology Result

Additional constraints led to a simpler shape similar to original concept.

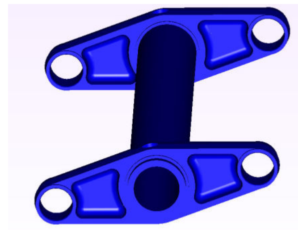
- Tube diameter has been maximized.
- End height has been maximized.
- Understanding boundary conditions and individual load case effects is important.

Combined density plot for all load cases

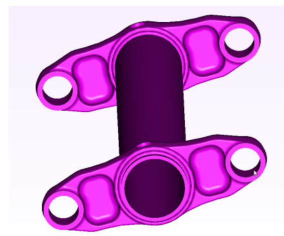


Final Design

- Tube made lighter and stiffer
  - Diameter: 4.0”→ 5.0”
  - Thickness: .55” → .25”
- The cast end pieces were given increased cross-sectional height.
- Weight is reduced 15 lbs, but stiffness is retained.



Original Design



Modified Design

Summary & Conclusions

- ArvinMeritor has found optimization is not “magic,” but it is very useful.
  - Benefits depend on the skillful usage. Skill comes with practice.
  - Optimization sometimes confirms the current design concept or suggest “obvious” improvements. These are still valuable results!
  - Optimization will see increased usage.
  - Optimization will be introduced earlier in the product development cycle.