Extreme Optimization

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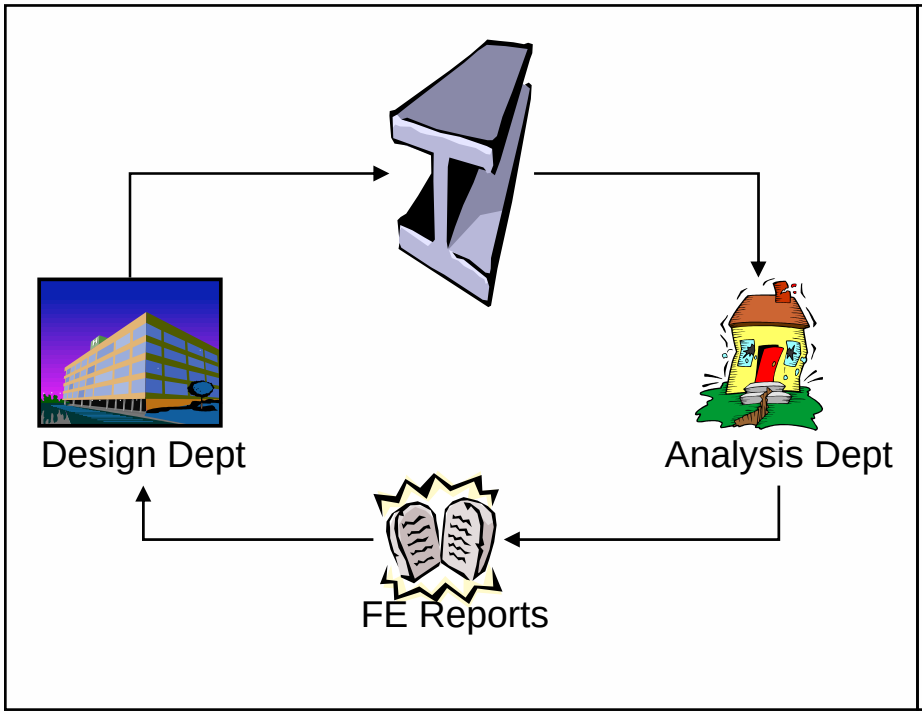
Background

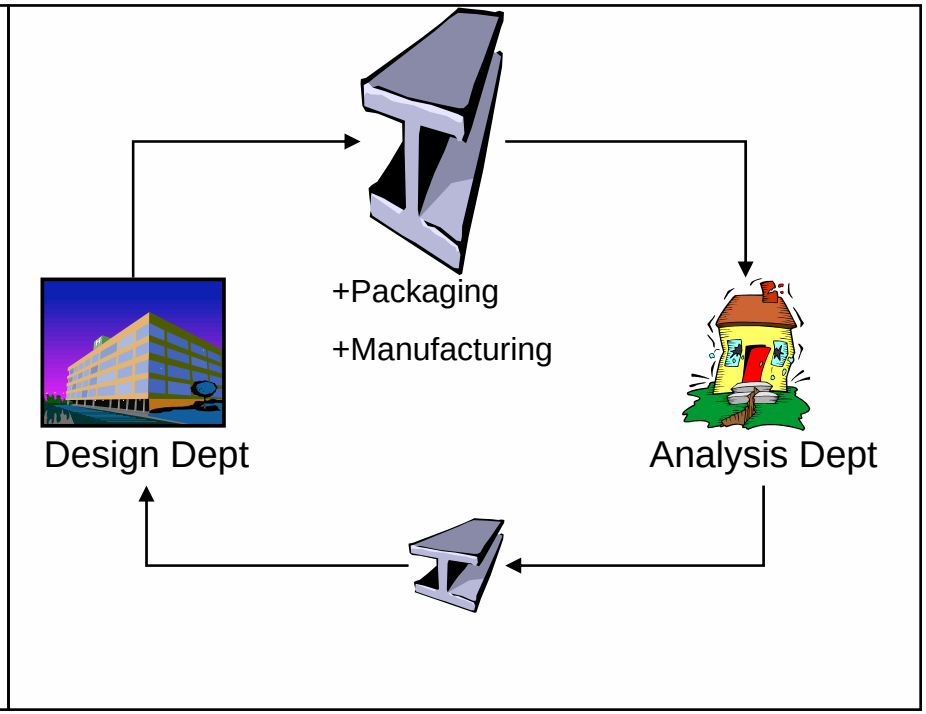
Conventional CAD / CAE component optimisation loop is inefficient.

Current process has many limitations.

Current Process



Extreme Optimization Process



Shape Optimisation

Optimisation requires a variety of strategies to obtain the best results. Shape optimisation algorithms are aimed at improving pre-existing FE meshes towards the end of the design cycle. Available in commercial codes and using X-OPT on a consultancy basis.

- Based on nature, conducting small improvements each generation, moving nodes ‘normal’ to surface
- Extensive use of volumetric and surface smoothing
- Can deal with a wide class of problems
  - But load paths should not change substantially
  - Stress, strain, ESE (stiffness) and fatigue life are the goals to be modified (with minimum mass as a product of the analysis)
  - Simple but effective

Constraints and Groups

Current algorithm is CPU intensive and requires access to a robust fast solver (MSC.Nastran).

Constraints

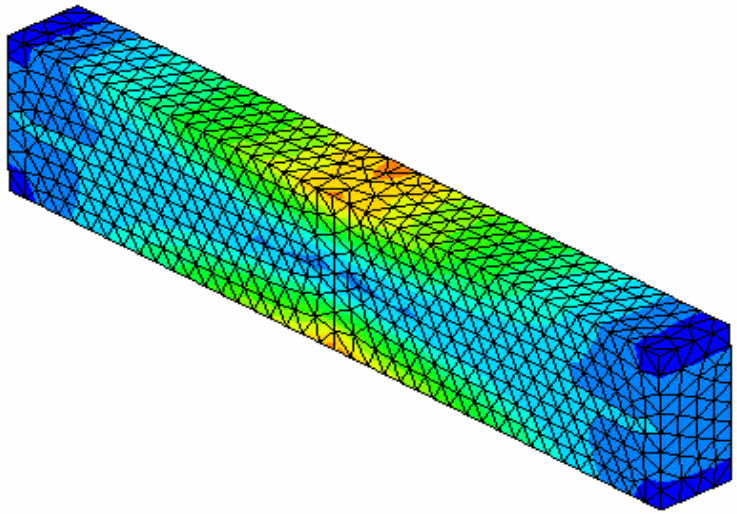
- Hard – areas on model that are fixed (bolt holes / styling details)
- Soft – areas that can move in a free form or defined direction
- Packaging – structures added for clash detection
- Manufacturing – draft angles / wall thicknesses

- Groups
  - Node and element groups used to define above relationships
  - CPU penalty for increasing complexity of constraints

Main Features

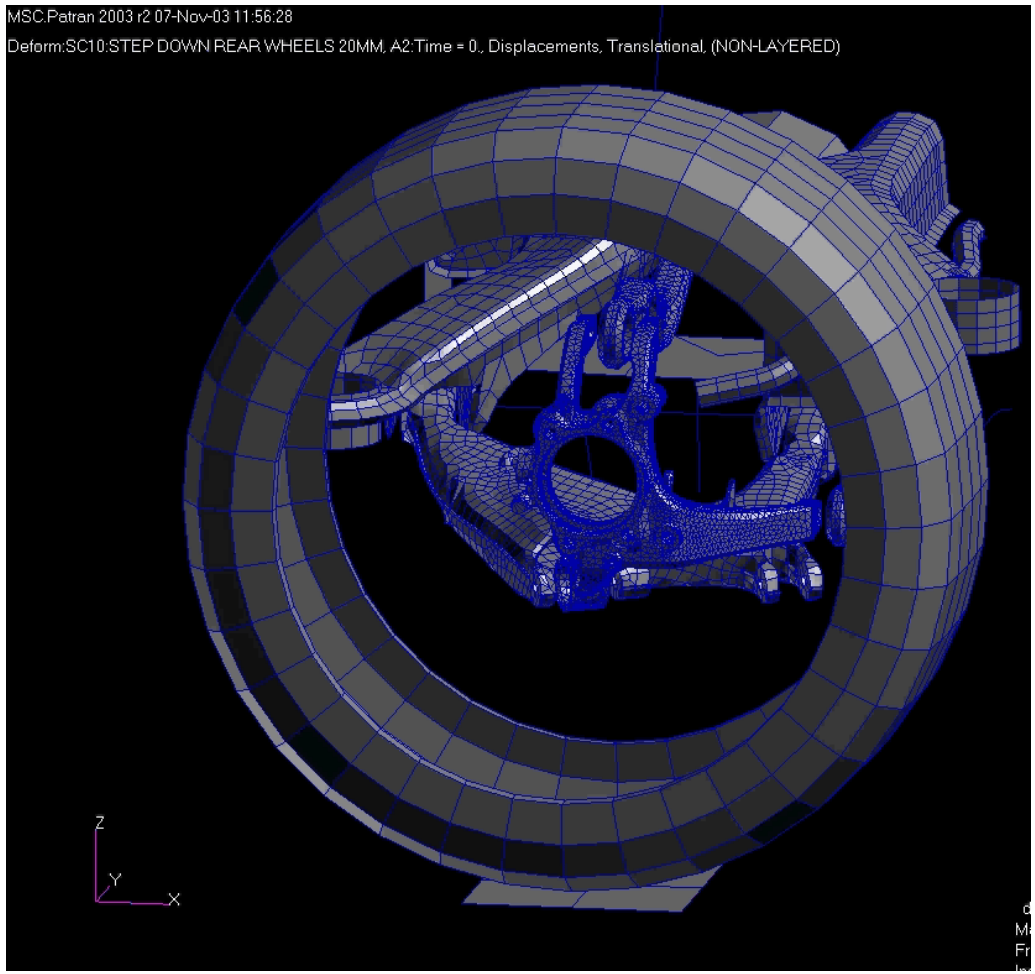
- Algorithm loves to eliminate stress concentrations – these are easily solved by a local smoothing improvement.
- Fatigue life unification or modification also solved by this process
- Deliverable from the process is a 3d Solid (STL VRML IGES) model for the designer to re master the part, rather than a FE report. This model fully describes the optimum geometry.
- Improves even highly optimised designs

Example 1 :Stability and Predictability



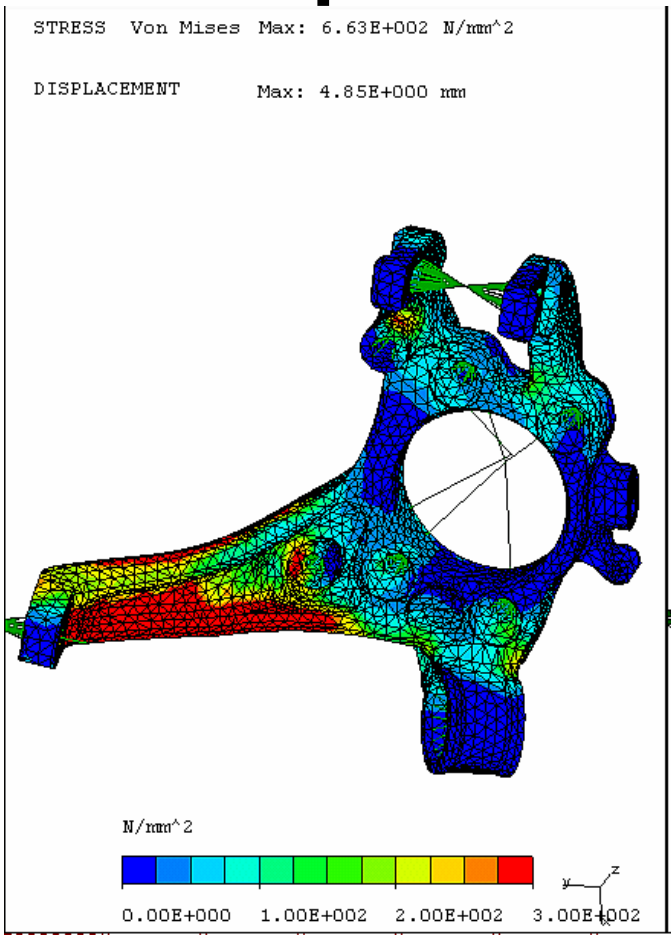
- Point load at centre must be distributed via RBE2 / RBE3
- Example shown prior to more surface smoothing
- Constant stress design criterion
- Doubly tapered I-Beam with fully parabolic web evolving

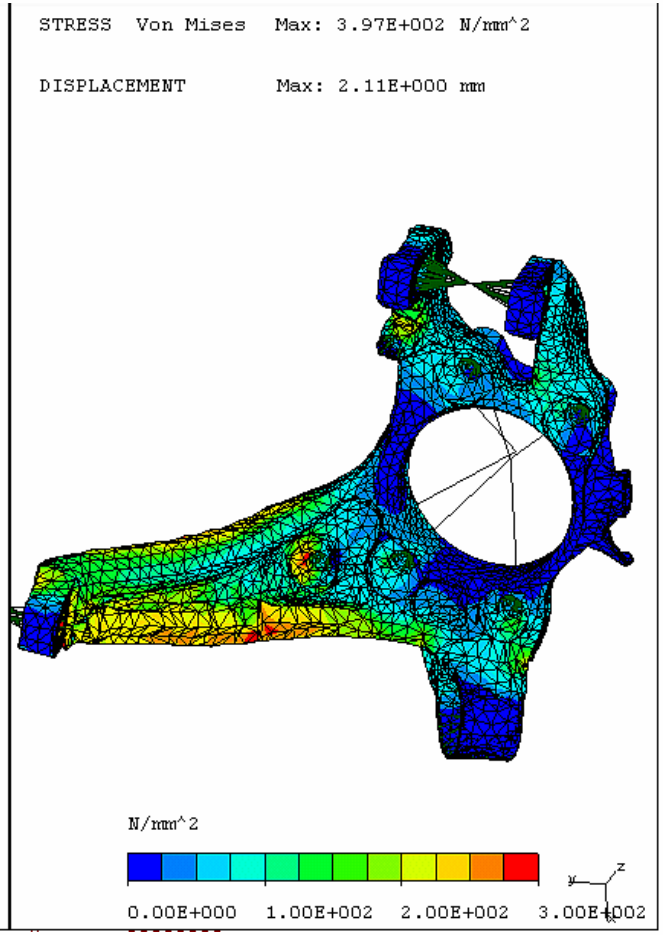
Example 2 : Automotive Knuckle



Multi link rear axle model shown

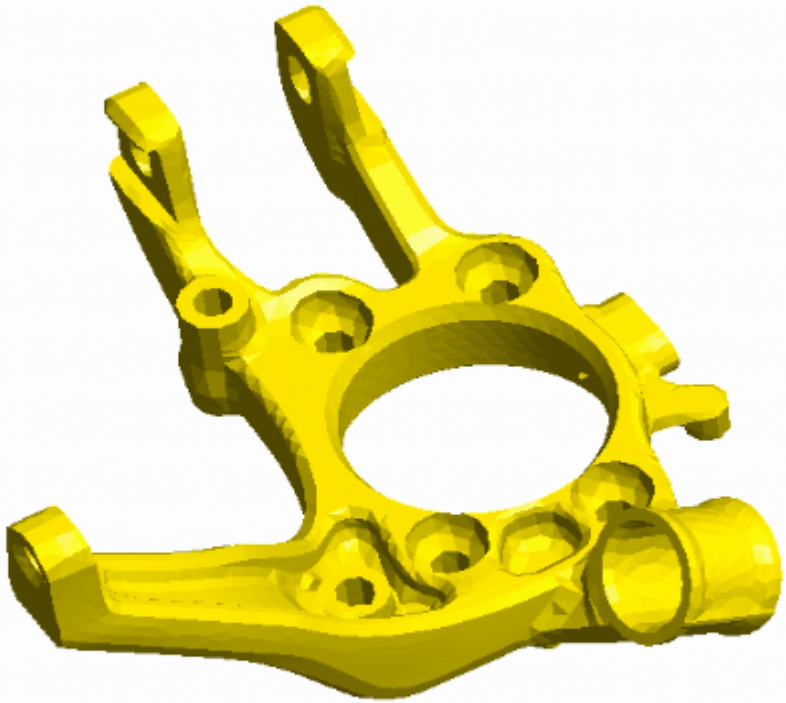
Example 2 : Stress Distribution





- Interim optimisation results for all load cases shown, prior to surface smoothing – mesh is at limit of stability
- Stresses reduced significantly
- Stiffness for all load cases improved

Example 2 : Automotive Knuckle



- Attachment point detail, bearing bore and bolt holes fixed
- Significant redistribution of mass
- Arm mass increase harvested from remaining region

Example 2 : Automotive Knuckle

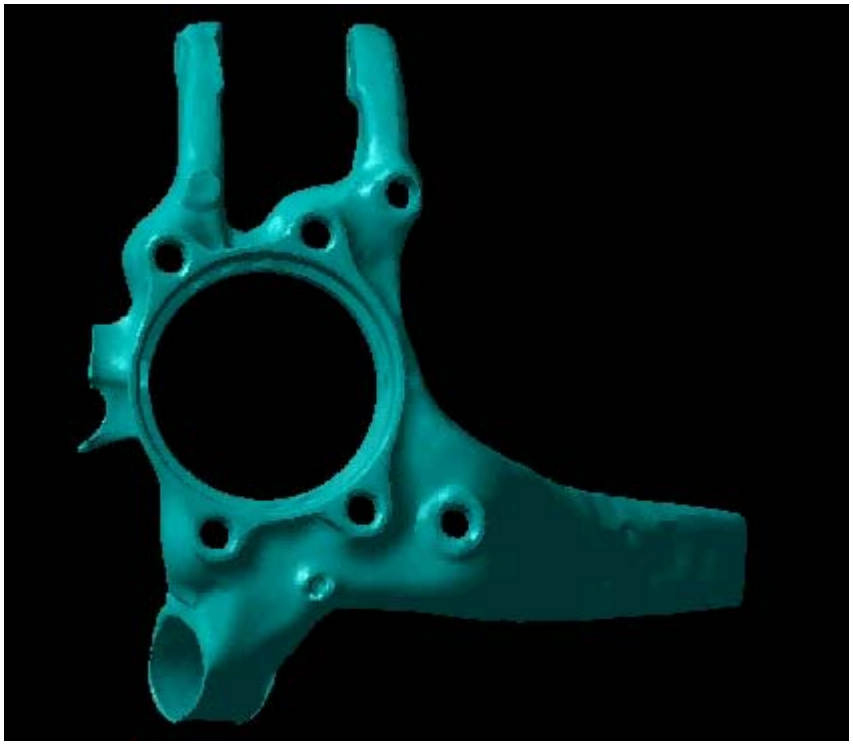
Note erosion of non important details

Hoop stress needs to be introduced in lower bush

Arm straightening is a significant event

Component mass reduced by 170g from 1.7Kg

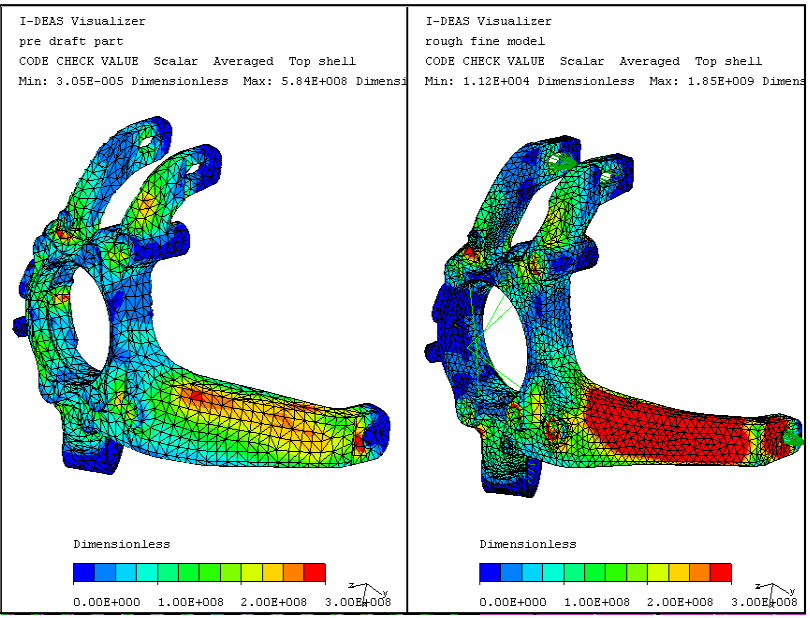
Example 2 : Solid Model



- Organic form after surface smoothing operation
- This solid model passed to CAD department to re master part
- Significant design direction given by the process
- Some manufacturing issues to resolve - undercuts

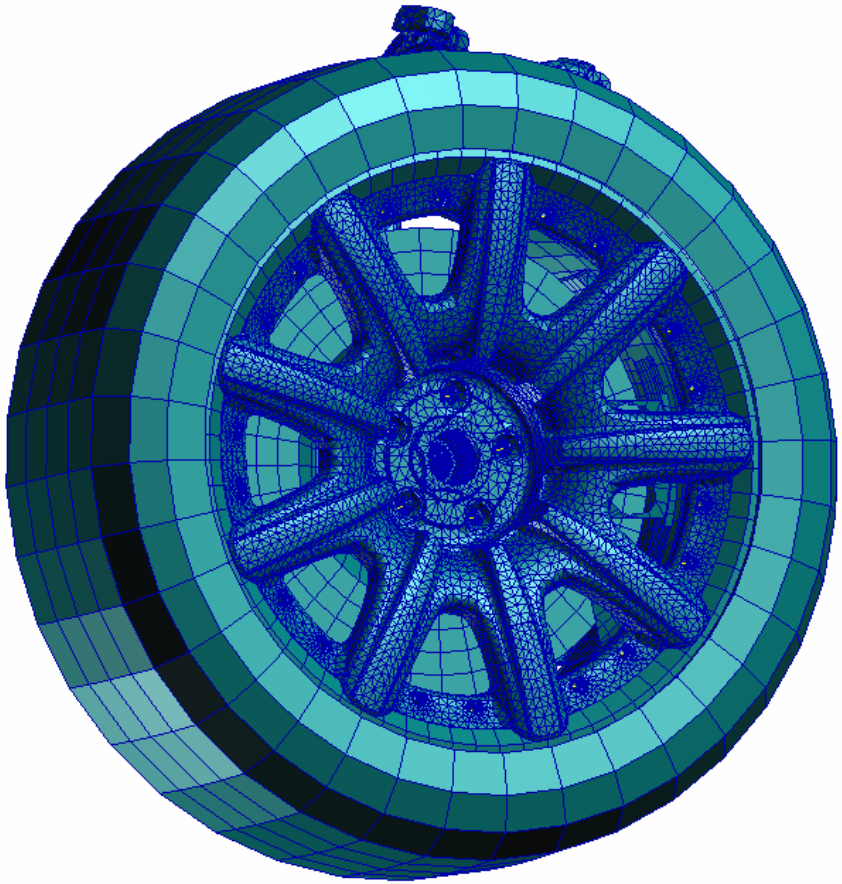
Example 2 : Re mastered part - comparison with original

NEW **OLD**



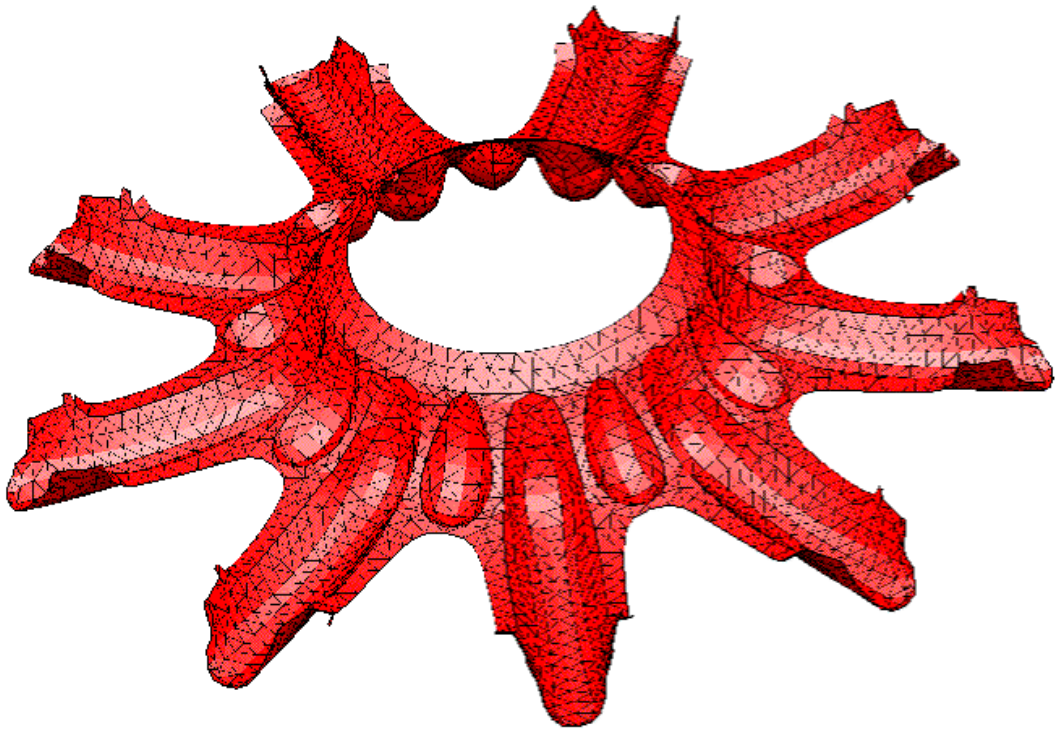
Load Case	NEW		OLD	
	Stress MPa	Peak Displacement	Stress MPa	Peak Displacement
1	421	0.074	507	0.175
2	352	0.990	583	2.560
3	583	2.560	1400	6.210
4	472	0.558	536	1.740
5	132	0.573	377	1.300
6	115	0.409	232	1.130
7	101	0.475	287	1.100
8	106	0.504	291	1.220
9	56	0.281	174	0.762

Example 3 : Fatigue Life Unification



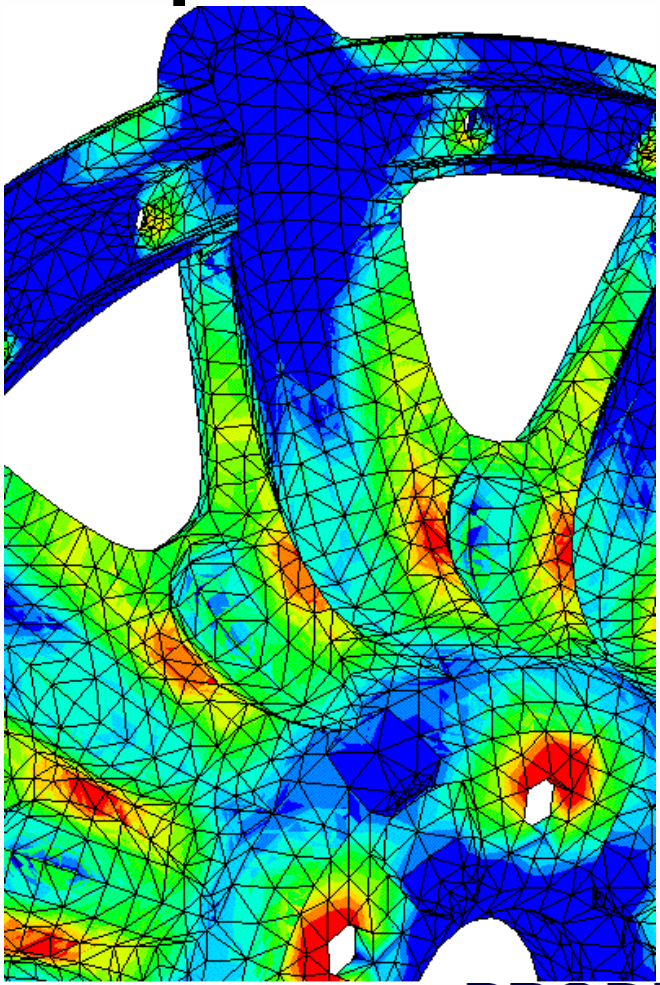
- Automotive 2 piece bolted rim wheel
- Objective – change reverse side of spokes. No changes to leave hub and rim connection
- Styled front surface to remain unchanged
- Component fatigue life excessive – reduce by an order of magnitude

Example 3 : Optimised Surface



- Rear surface shown
- Changes to profile very subtle
- Significant surface and core smoothing performed to extend the mesh life
- Forged wall thickness constraints employed

Example 3 : Life Reduction



- Component fatigue life reduced by a factor of 10
- Position of lowest cycle life extended to cover larger area
- Component mass reduced from 5.2Kg to 4.0Kg
- More strain in spoke region also beneficial for side impact
- Rear surface only marginally changed – no manufacturing issues

Conclusions

- A shape optimization algorithm has been developed that allows an analyst to optimise a structure for many load cases and design targets, maintaining packaging and manufacturing constraints
- Because the analyst has control of the geometry, mass reduction / geometry improvements are possible in a shorter period of time
- The deliverable from the process is a solid model showing the desired geometry rather than an FE report to distribute to the CAD department
- With tools like X-OPT, optimisation even late on in the design cycle is possible

Acknowledgements

Examples 2 and 3 given by kind permission of Bentley Motors Limited.