Optimised Topology +

Lotus Engineering

03/11/2021

sarginsons

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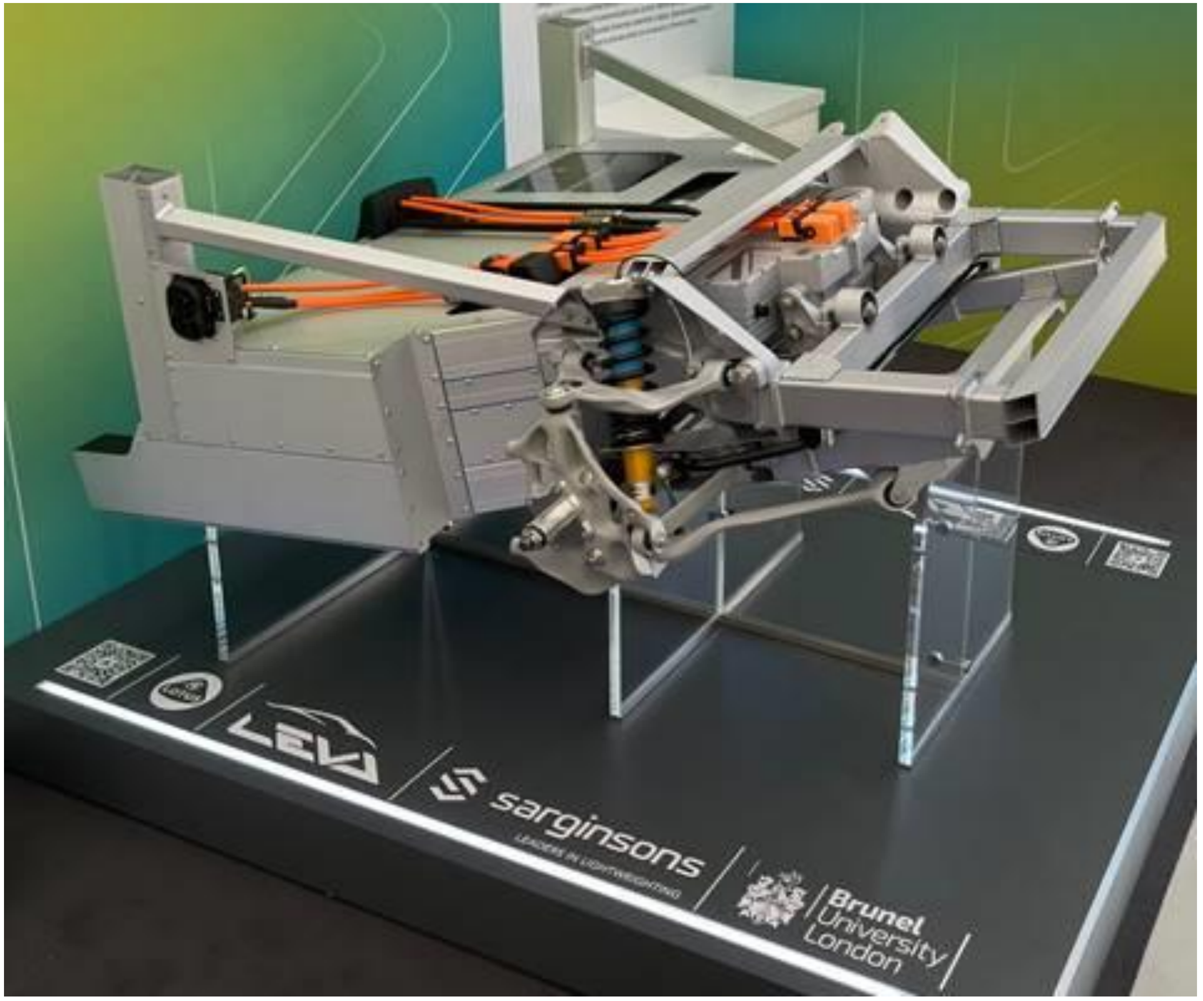
Case Study – Rear Chassis Upright Casting

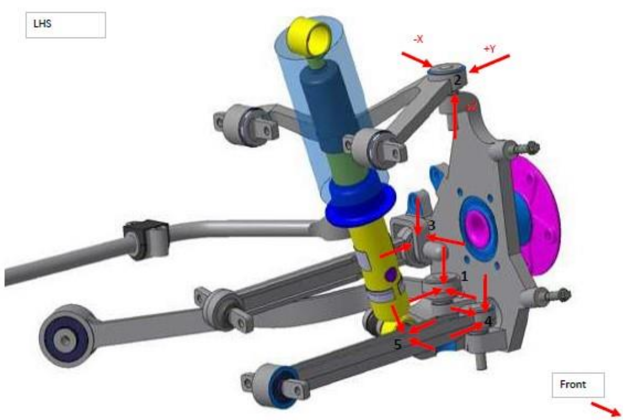
Key Objectives:-

- To outline how Sarginsons are looking to develop solutions using optimised topology
- Highlight potential issues with these forms from a casting and optimised topology perspective
- Demonstrate how Sarginsons can simulate and map the variable mechanical properties inherent in optimised forms through casting and heat treatment
- Show the impact that these variations have when re-simulated in LS-DYNA, and how casting performance is affected

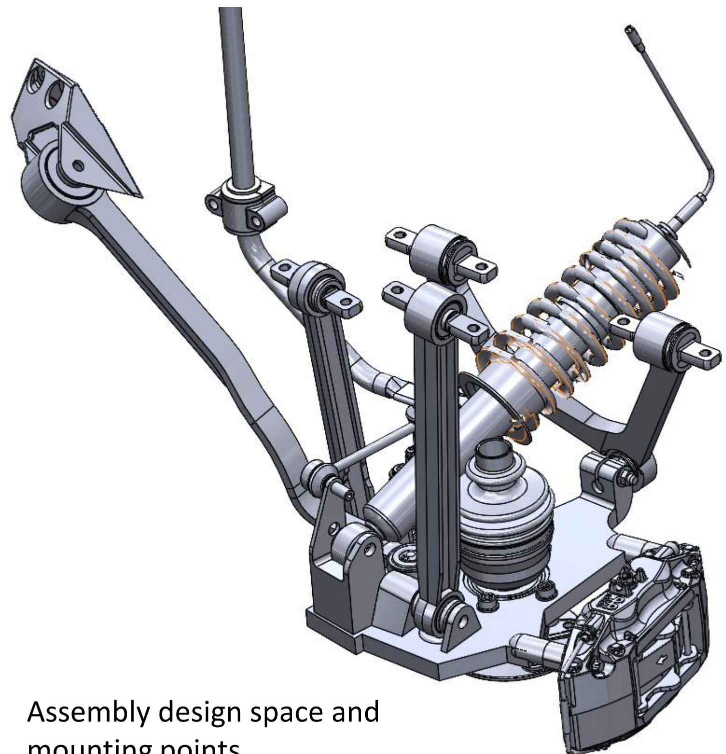


Base Line Data

	Relative to Knuckle			
LHS	No.	X	Y	Z
Longitudinal Control Arm Inner LH				
Lateral Control Arm Inner LH				
Longitudinal Control Arm Outer LH	1	-2717.6	2330.62	236.4
Upper wishbone front inner LH				
Upper wishbone rear inner LH				
Upper wishbone outer LH	2	5833.44	-9261.58	-1831.26
Outer track rod ball	3	-370.77	5702.43	382.5
Inner track rod ball				
Lateral Control Arm Outer LH	4	770.94	8291.8	215.44
Hub Bearing LH		0	0	-18194
Damper Lower	5	-3516	-7063.3	19190.9
Damper Upper				
All Co-Ordinates in Global - X+ towards rear of car, Y+ to right, Z+ up,				
	sum	0.01	-0.03	-0.02

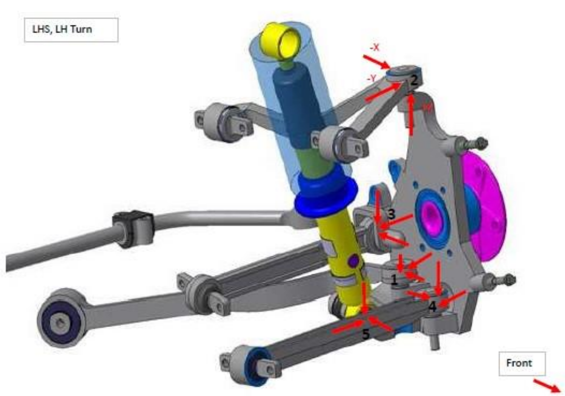


Load Data 3g Bump



Assembly design space and mounting points

Left hand cornering		Relative to Knuckle		
LHS		X	Y	Z
Longitudinal Control Arm Inner				
Lateral Control Arm Inner				
Longitudinal Control Arm Outer	1	-1387.72	-1190.45	120.67
Upper wishbone front inner				
Upper wishbone rear inner				
Upper wishbone outer	2	1483.93	5498.02	-1085.43
Outer track rod ball	3	-110.77	-1676.44	111.81
Inner track rod ball				
Lateral Control Arm Outer	4	854.36	-9170.2	236.21
Hub Bearing		0	4852	-3967
Damper 2 Lower	5	-839.8	1687.06	4583.74
Damper 2 Upper				
	sum	0	0.01	0



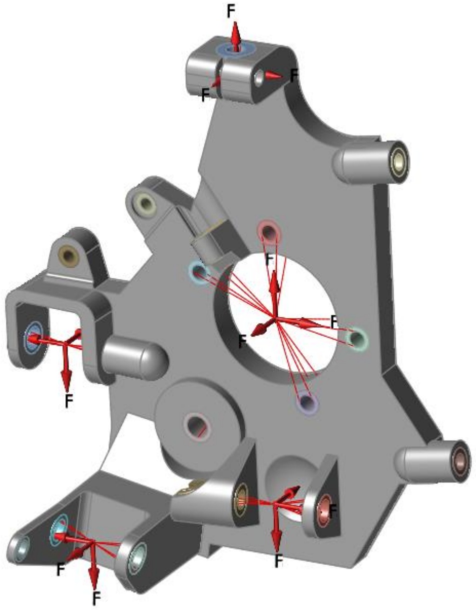
Load Data 0.8g lateral 2.5g Bump

Default TYE figures (A356 T6):-

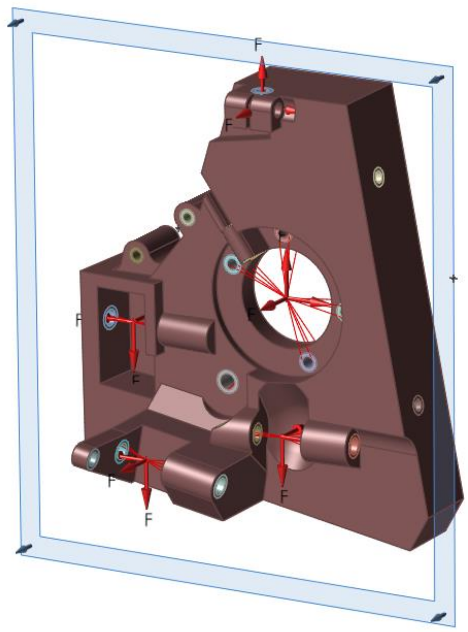
- Elongation – 5%
- 0.2% proof stress – 195MPa
- UTS – 250MPa

Altair Inspire

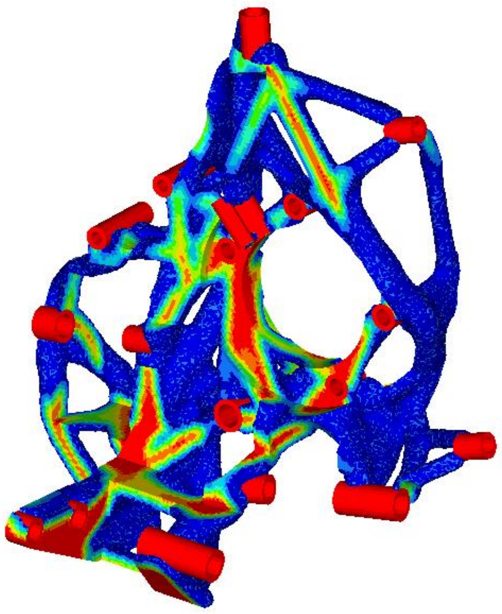
- Workflow Example



Model Import & Baseline



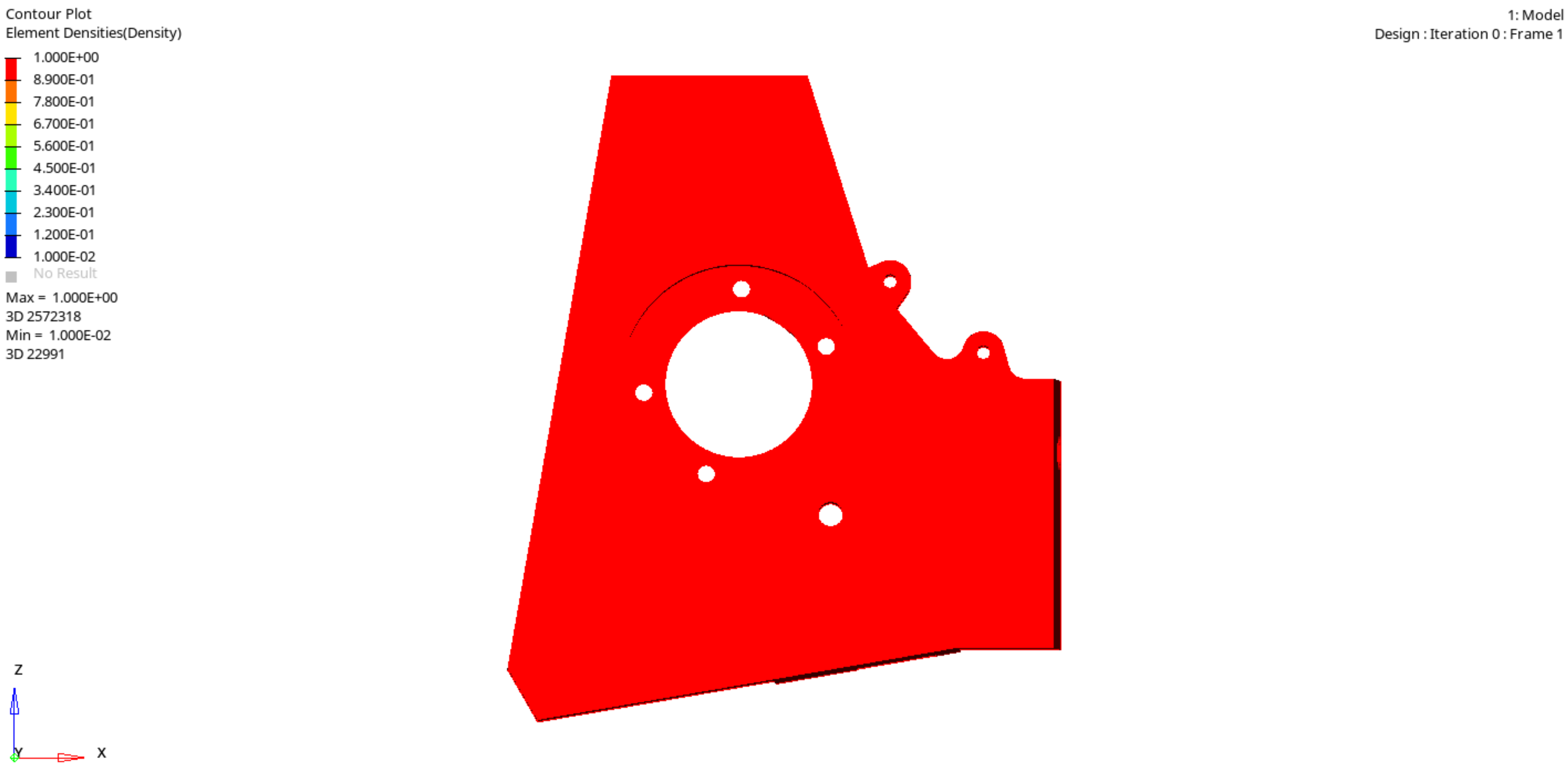
Design Space Definition



Analysis & Optimisation

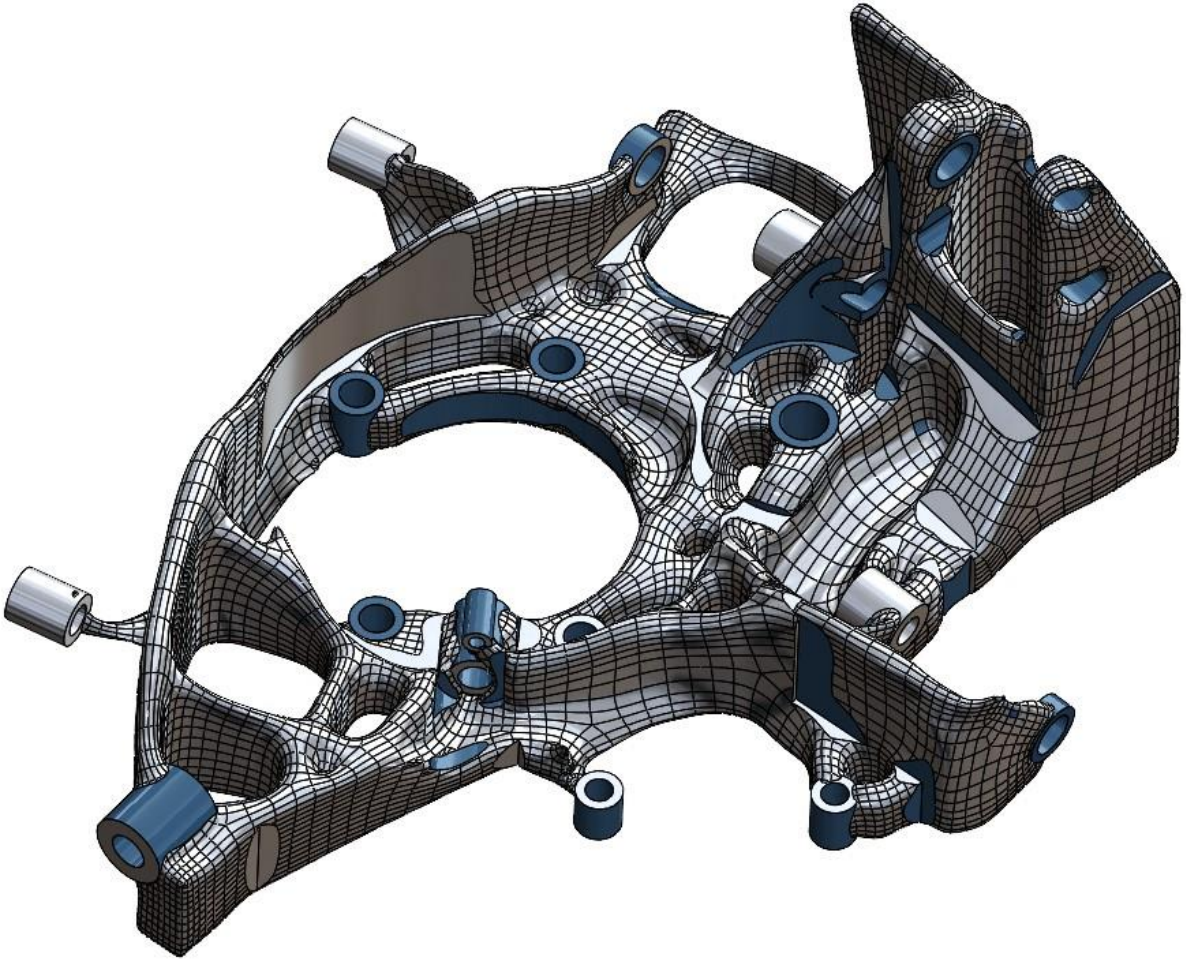
Altair Inspire

- Results Output Example

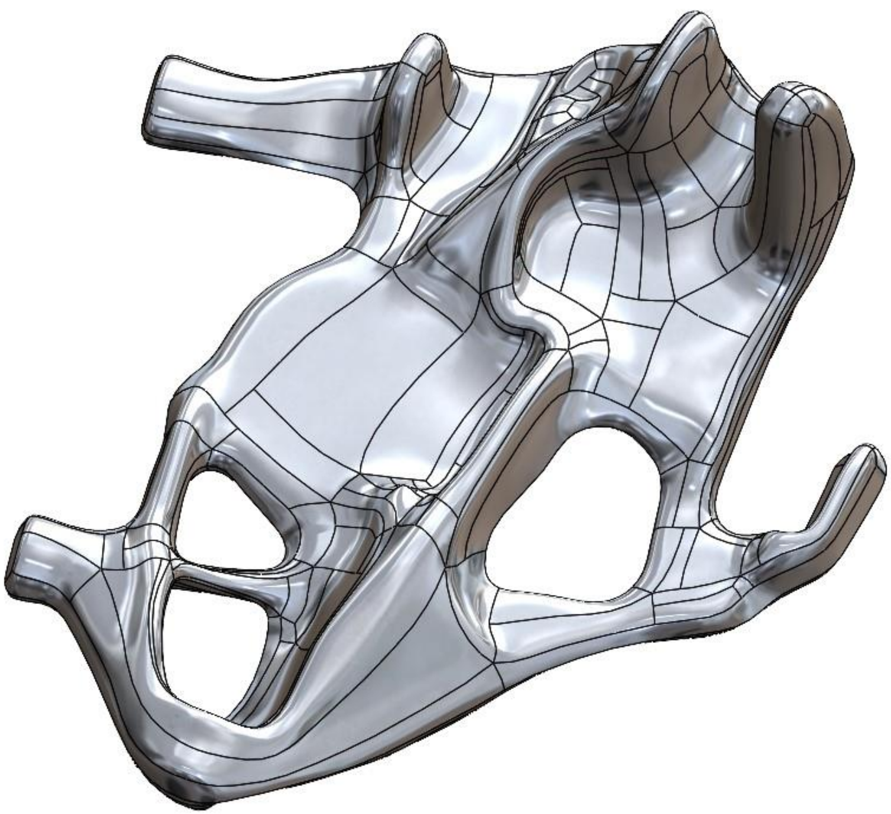


Initial Cast Form

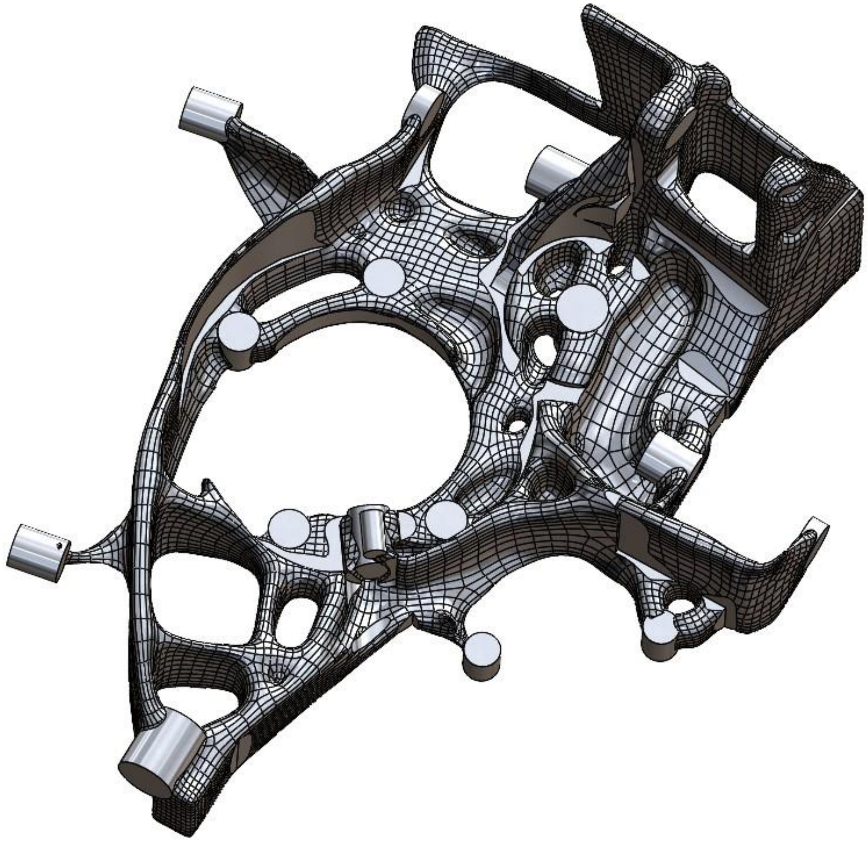
- Minimum material form generated using Altair Inspire software (OptiStruct)
- Low Pressure Die Casting approach
- FOS of 1.5
- 4mm min wall, 3 degrees draft
- Single Draw Optimisation
- Stress Concentration Around the Damper Mount Point, leading to increased mass locally
- Certain assumptions made for mounting points (could be optimised)
- Further casting development work required.



Form Comparisons



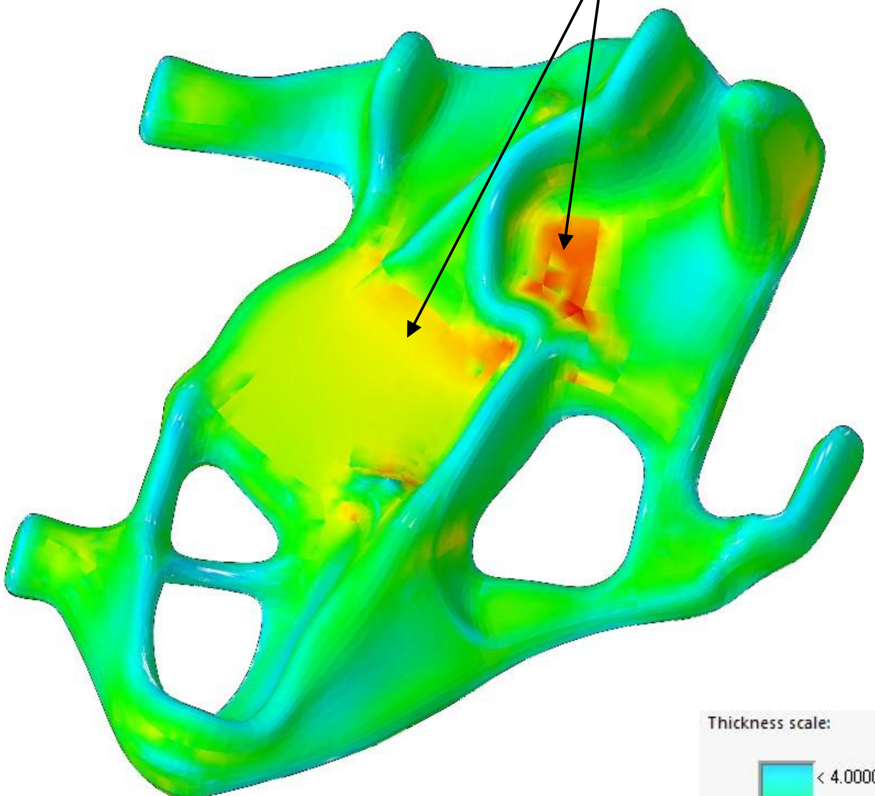
Lotus Optimised Cast Form – 4.13kg
(49% higher mass)

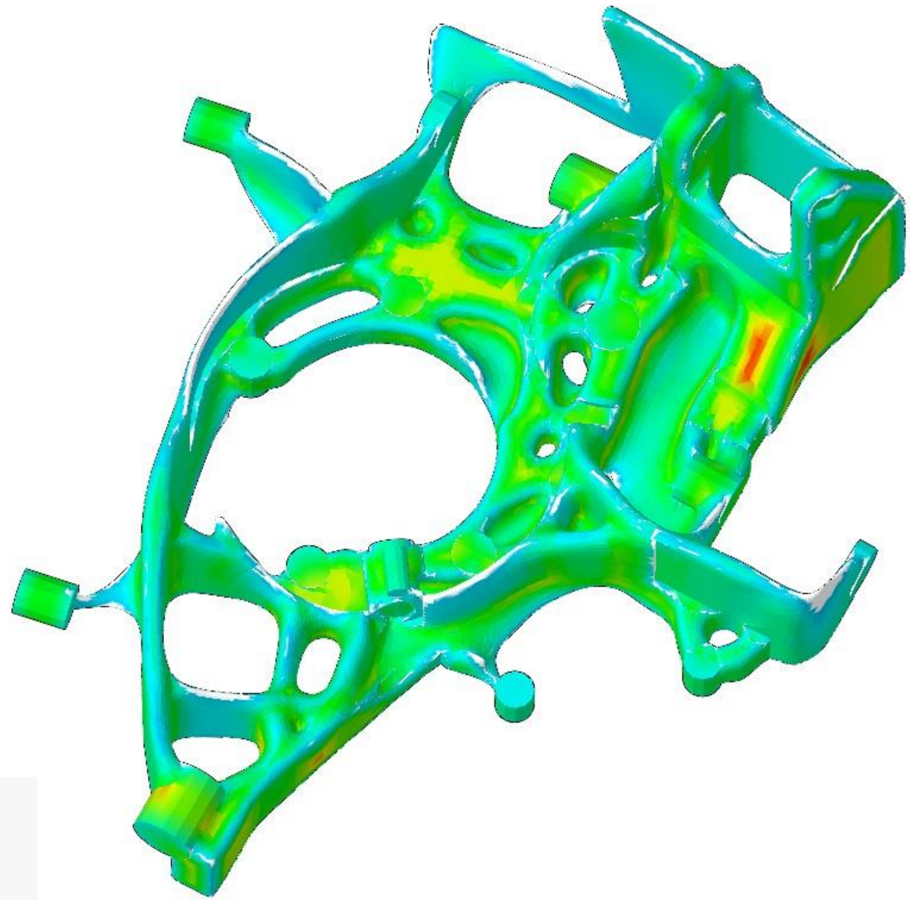


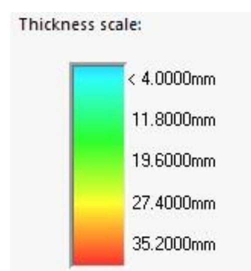
New Optimised Cast Form – 2.78kg

Wall Section Analysis

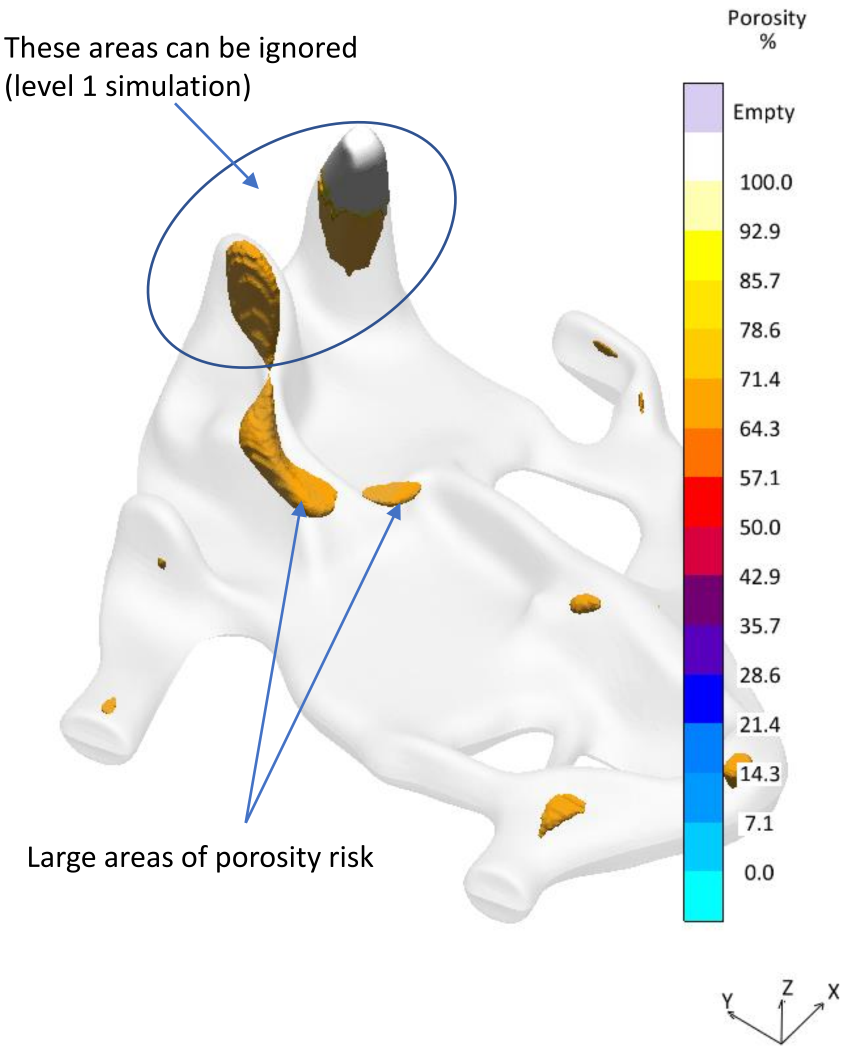
Large areas of isolated heavy sections. These can be problematic to feed, leading to localised porosity and comprised integrity



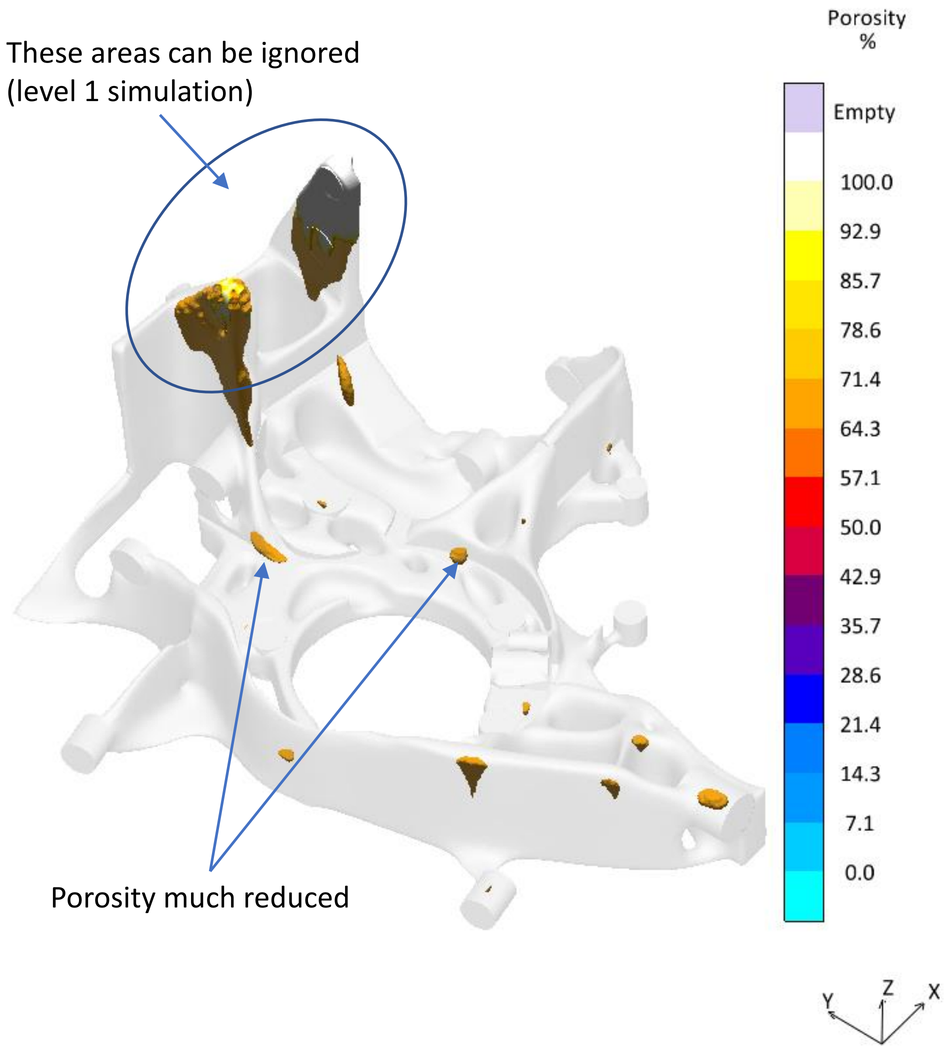




High-Level Porosity Predictions (Level 1)



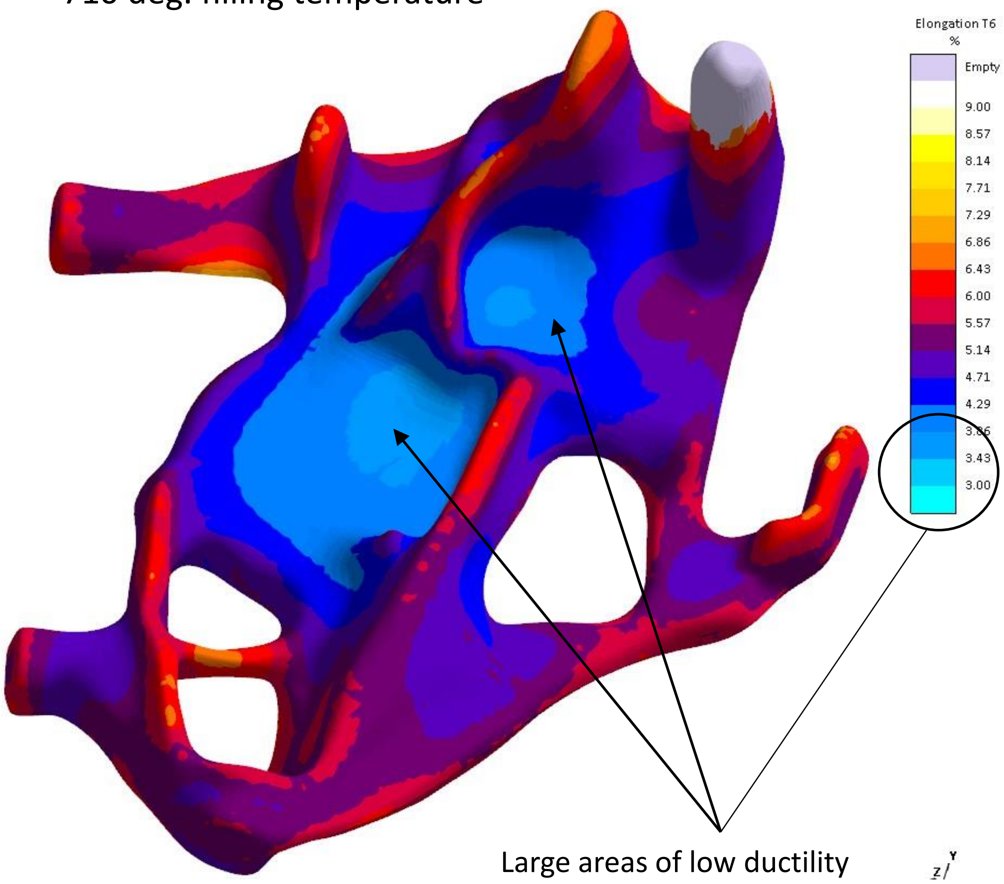
v01
Cycle 1, Solidification & Cooling until Eject, Porosity
51.544s, 100.00 %
X-Ray: on, range [70.00, 100.00] %

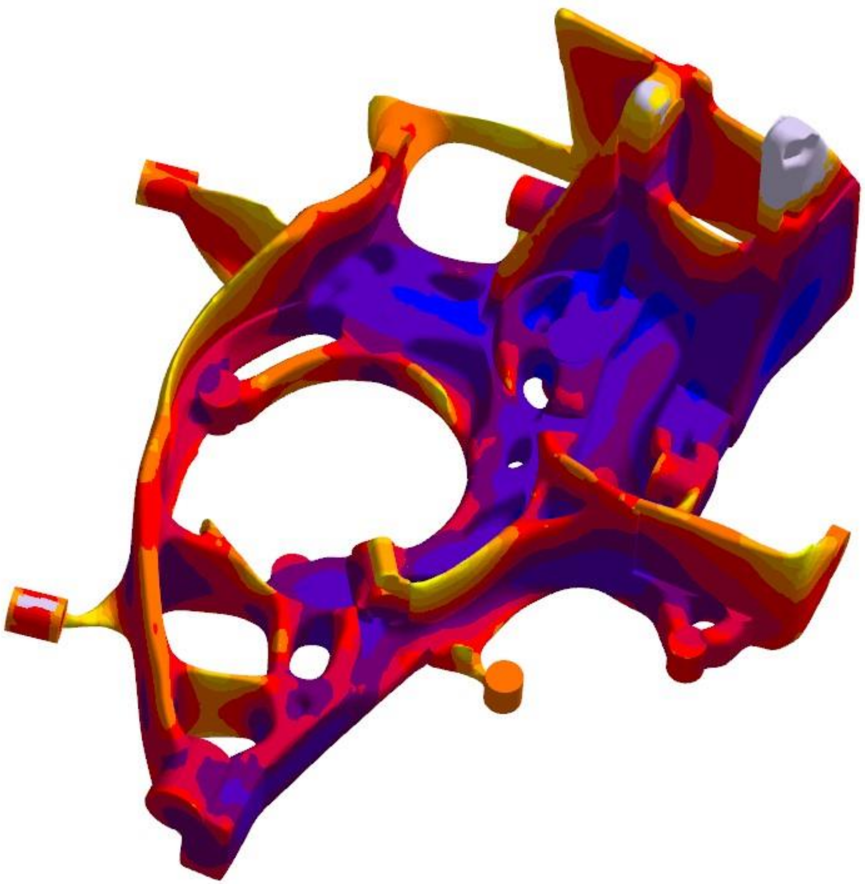


v02
Cycle 1, Solidification & Cooling until Eject, Porosity
25.959s, 100.00 %
X-Ray: on, range [70.00, 100.00] %

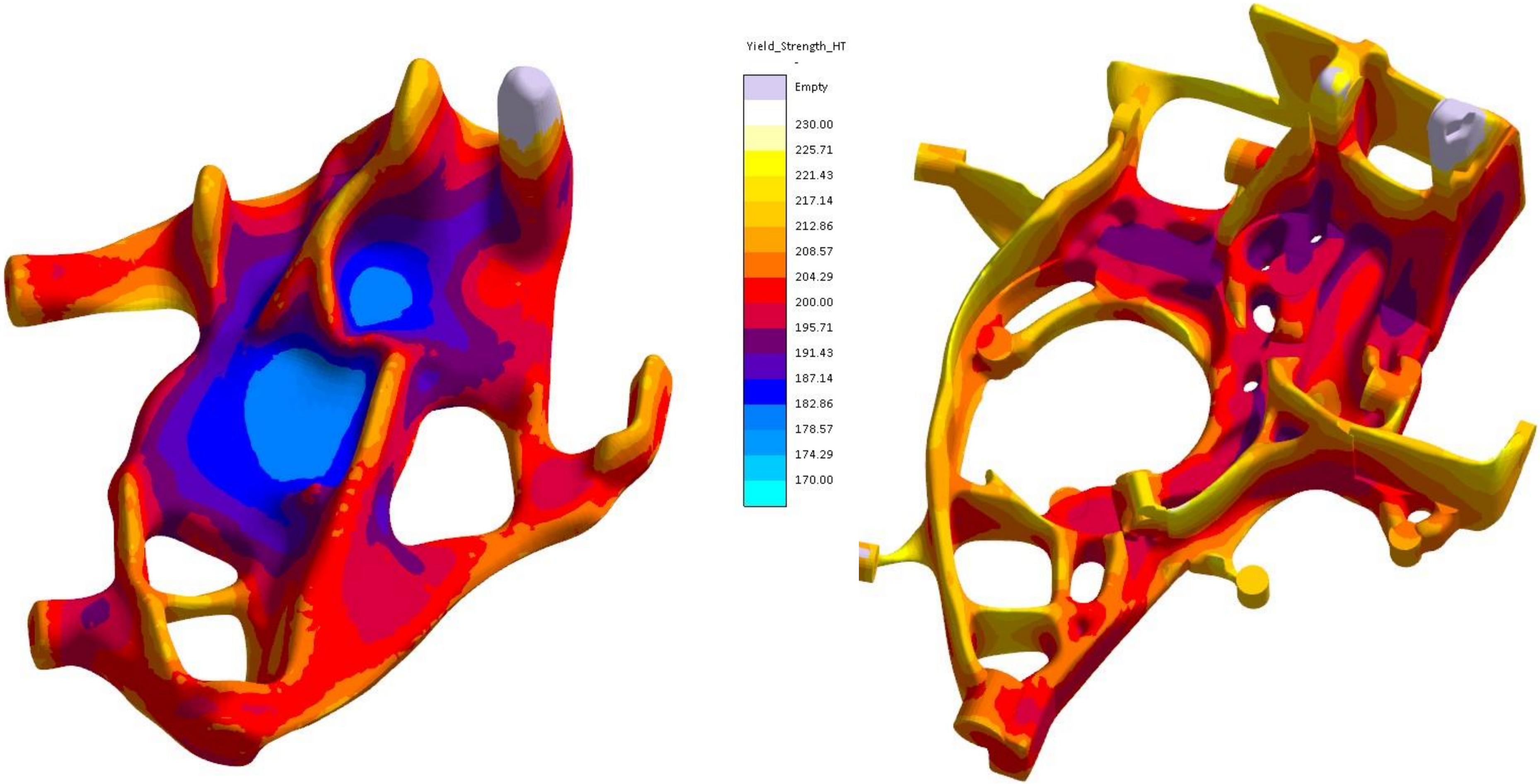
Mechanical Property Simulation - Elongation

- Low Pressure Level 1 MagmaStress Simulation (no feeds)
- A356 T6
- Steel tooling block
- 710 deg. filling temperature

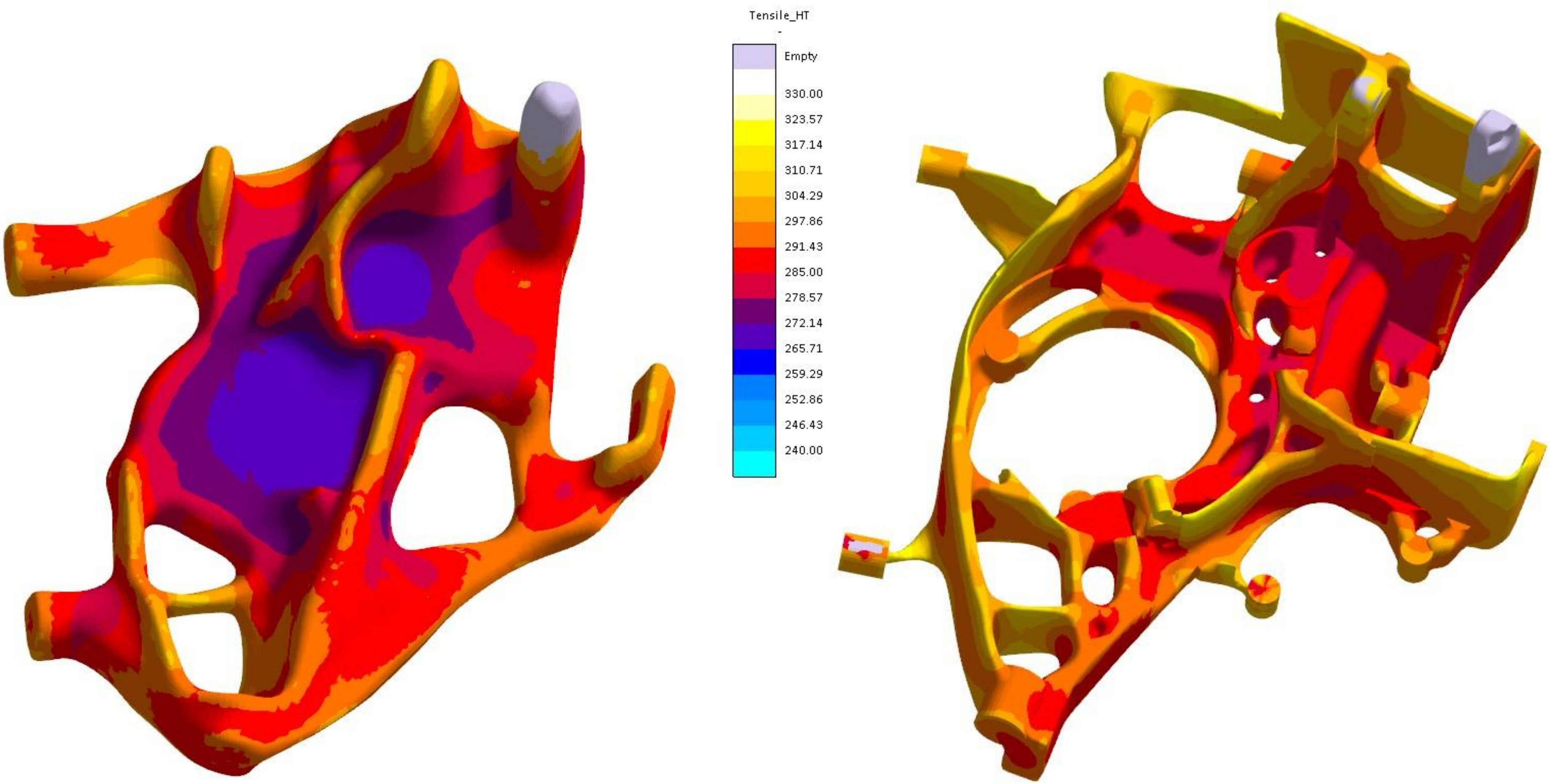




Mechanical Property Simulation - Yield



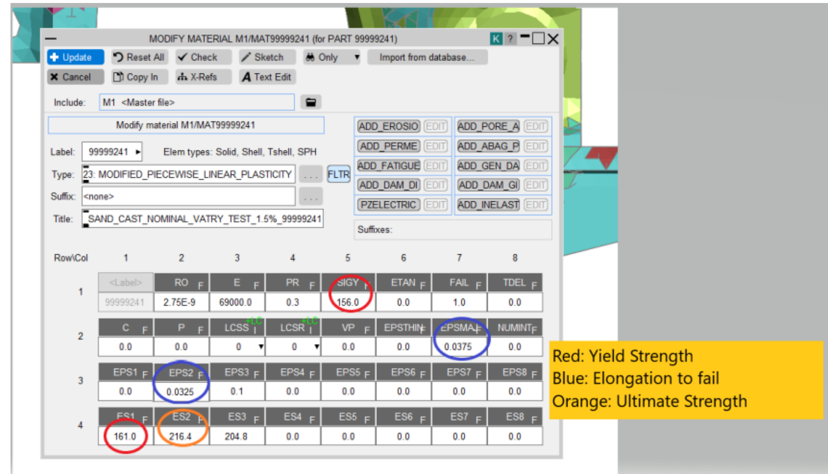
Mechanical Property Simulation - UTS



Mapping Simulated Data to LS DYNA

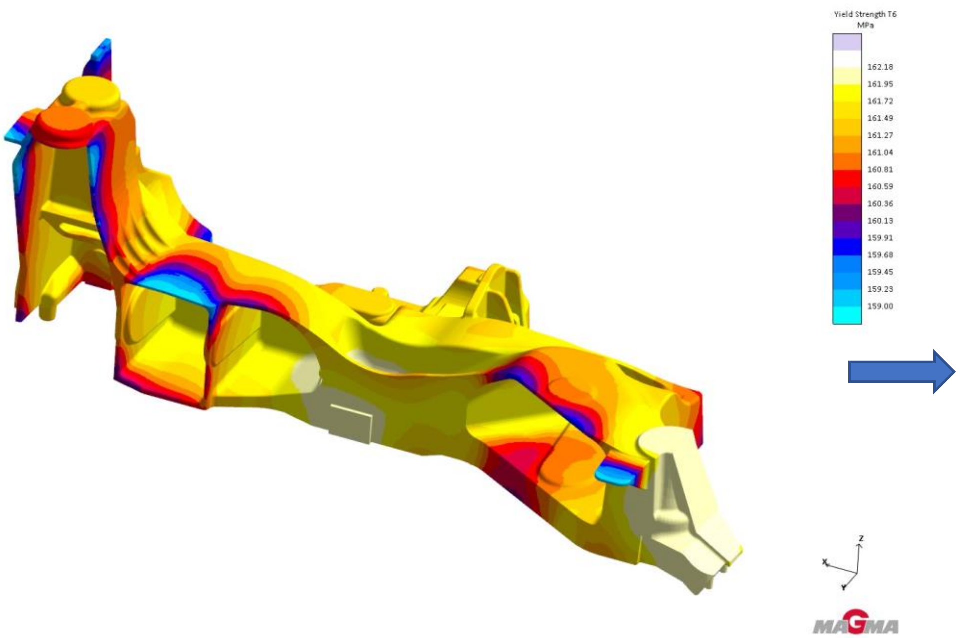
Mechanical Property Variables

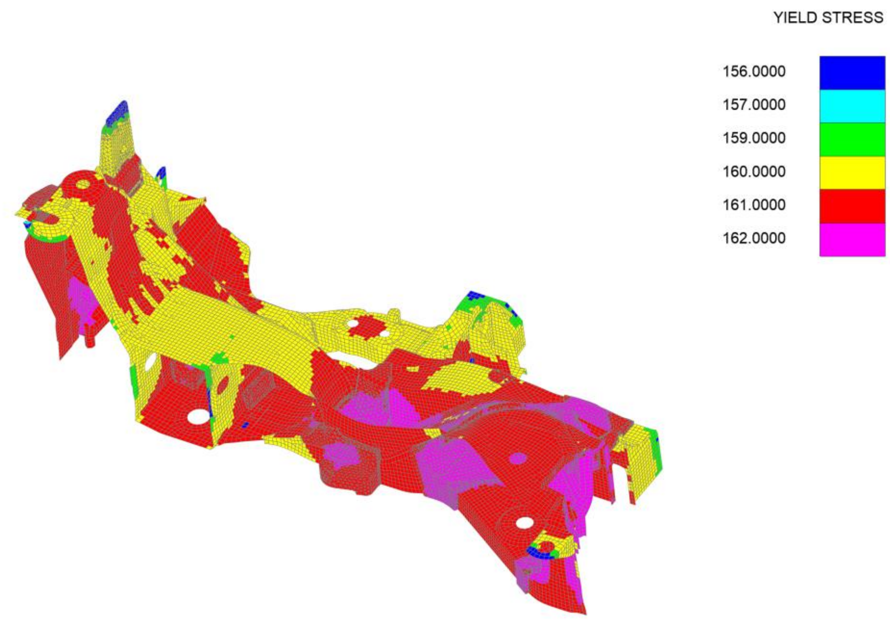
- Simulation of TYE mechanical properties inherent across cast form
- Full range of figures specified, with process, topology and alloy selection considerations
- Through process approach with cast data used sequentially for post operations such as heat treatment



Data Mapping with Optimised Banding (Pioneered by Sarginsons)

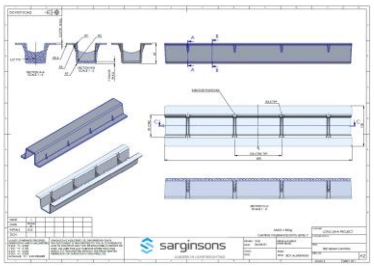
- TYE figures banded into customer specified levels to allow practical use in FE packages
- Data mapped onto material cards for seamless CAE import.



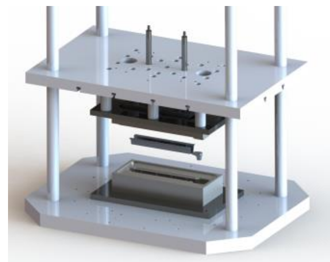


Simulated Mechanical Property Verification

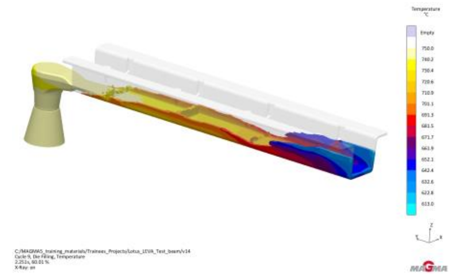
- Test Beam casting designed by Sarginsons in collaboration with an automotive partner
- All simulation work completed including TYE predictions
- Castings manufactured and subjected to 3 point bend testing



Casting Design



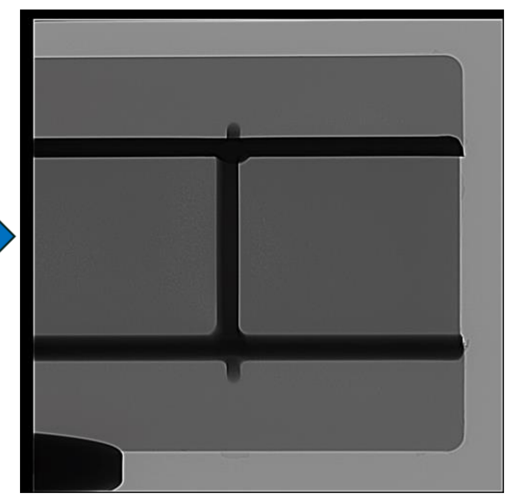
Tooling Design



Casting Simulation

Die Manufacture

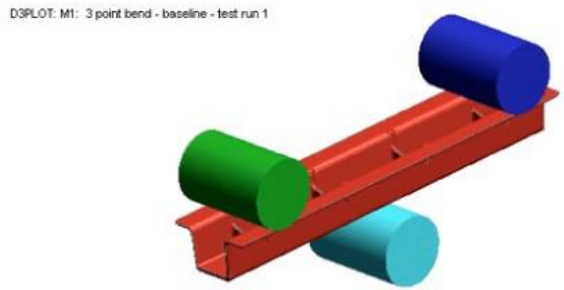
Raw casting

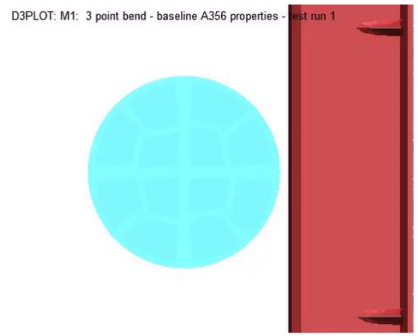


Real-Time X-Ray

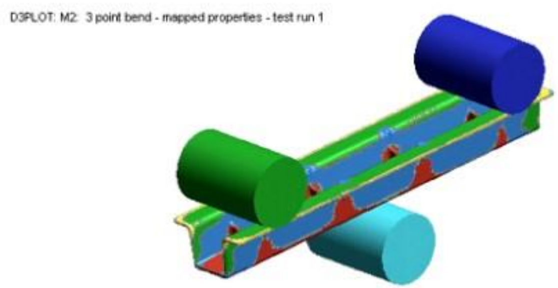
3 Point Load Testing – CAE Development

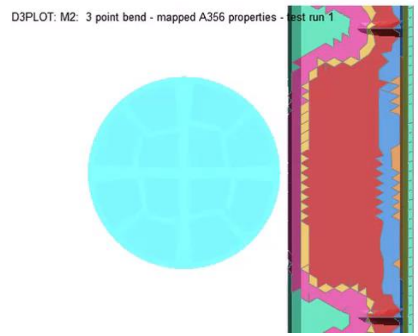
Force/Displacement Simulation



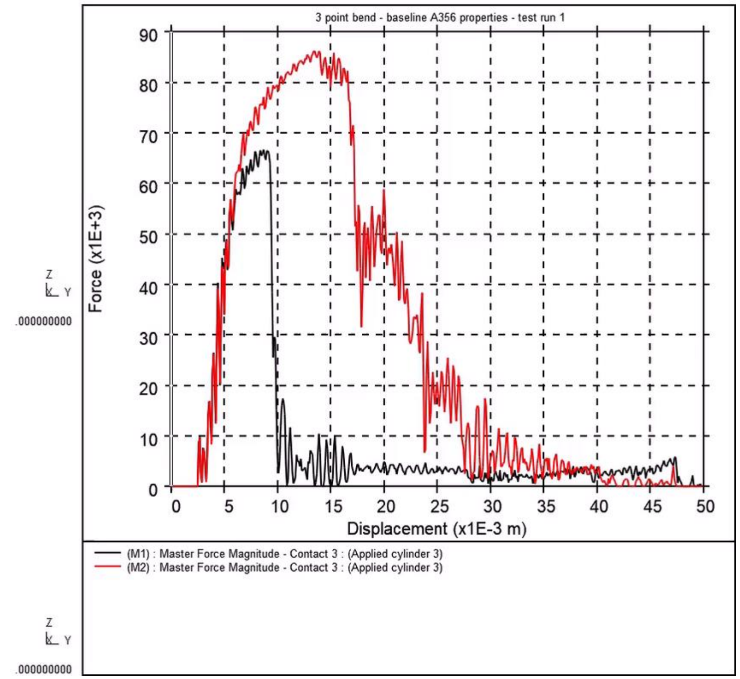


Baseline
A356 T6
properties





Mapped
A356 T6
properties



The Test Beam with fixed TYE figures across the form distorts and fails at a significantly different rate to the Beam where we have simulated the variable mechanical properties through LPDC and heat treatment.

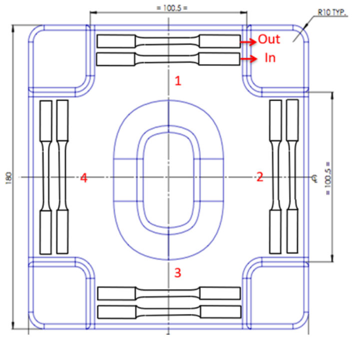
Impact of Heat Treatment Variables

Aging heat treatment – TYE (A356)

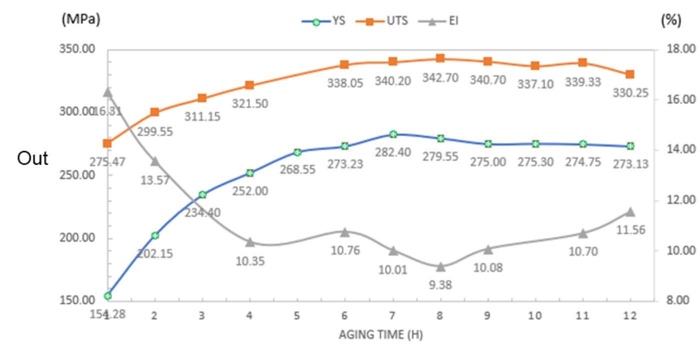
<u>Baseline A356 T6 material properties (Used in current Lotus CAE work)</u>

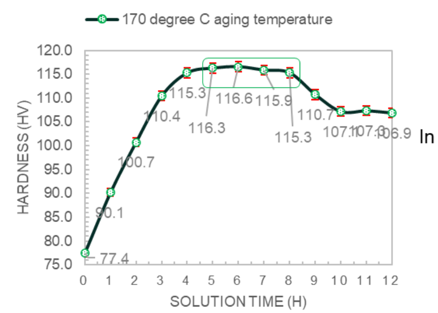
Baseline Proof Stress	210 MPa
Baseline Ultimate Stress	260 MPa
Baseline % Elongation	4 %

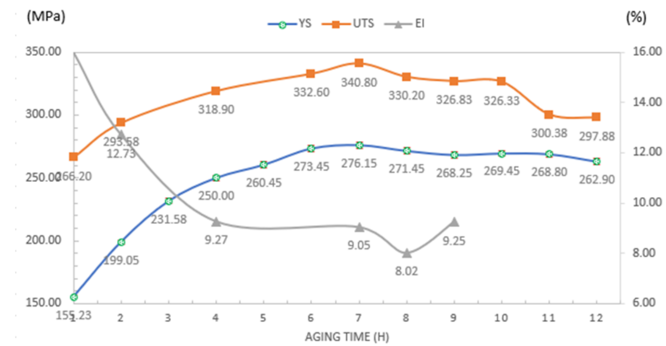
- Sarginsons have a comprehensive database of mechanical property impact due to heat treatment variability.
- In this programme two ageing parameters were chosen, simulated and test bars taken.
- Test run 1, with a lower ageing time, resulted in higher elongation (ductility) but lower UTS and Proof Stress levels than test run 2 with an extended ageing time
- Combined with the variability exhibited in cast form due to design geometry and cooling rates, this can significantly impact of the success of the design.
- As part of a digital twin design loop aligned with considered tooling approach , key mechanical targets can achieved



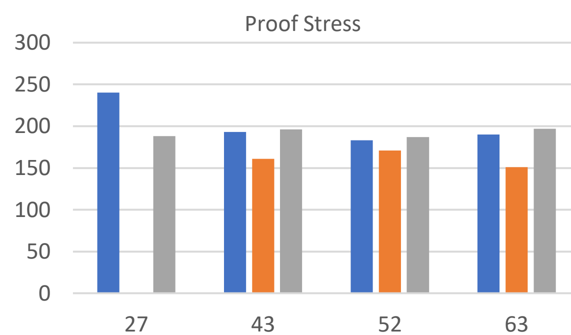
540C 6h solution + 170 C aging heat treatment





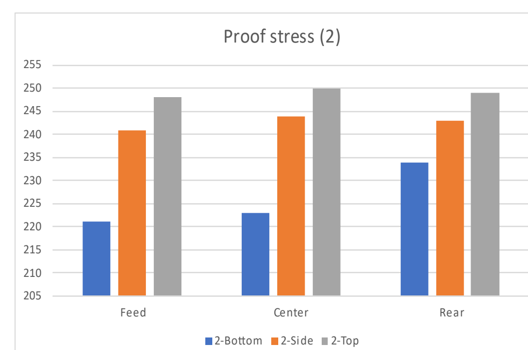


Test Run 1 -3 hour HT ageing



160-220MPa

Test Run 2 - 5 hour HT ageing

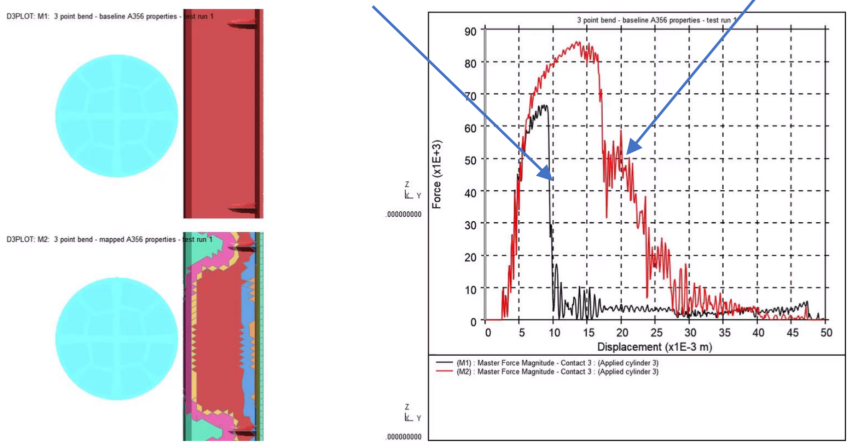


220-250MPa

CAE simulation and result calibration

Result using fixed standard CAE data

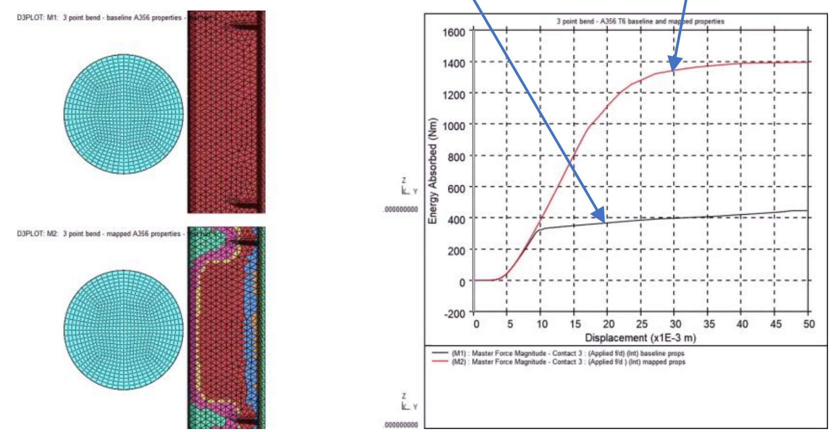
Simulated result



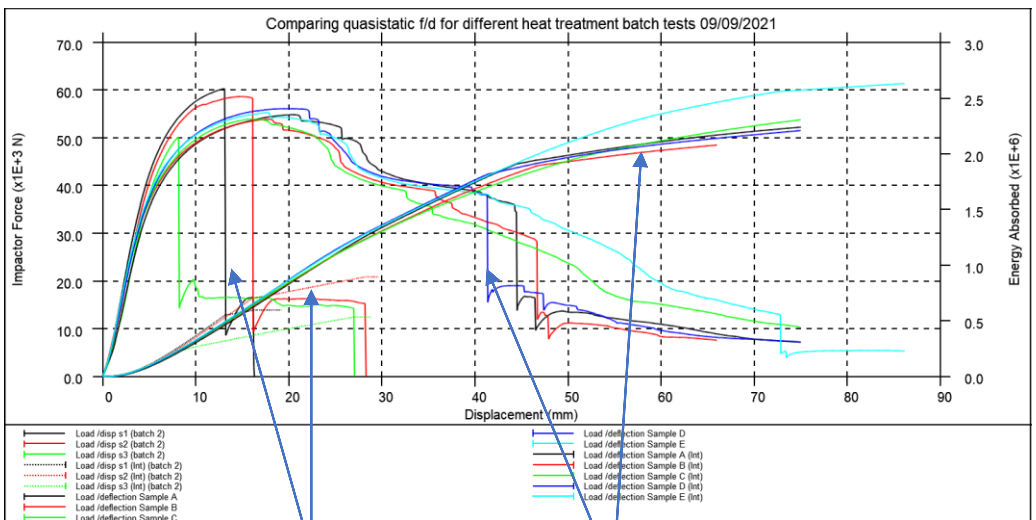
Force/Displacement Simulation (Test Run 2)

Result using fixed standard CAE data

Simulated result



Energy absorption /Displacement Simulation (Test Run 2)



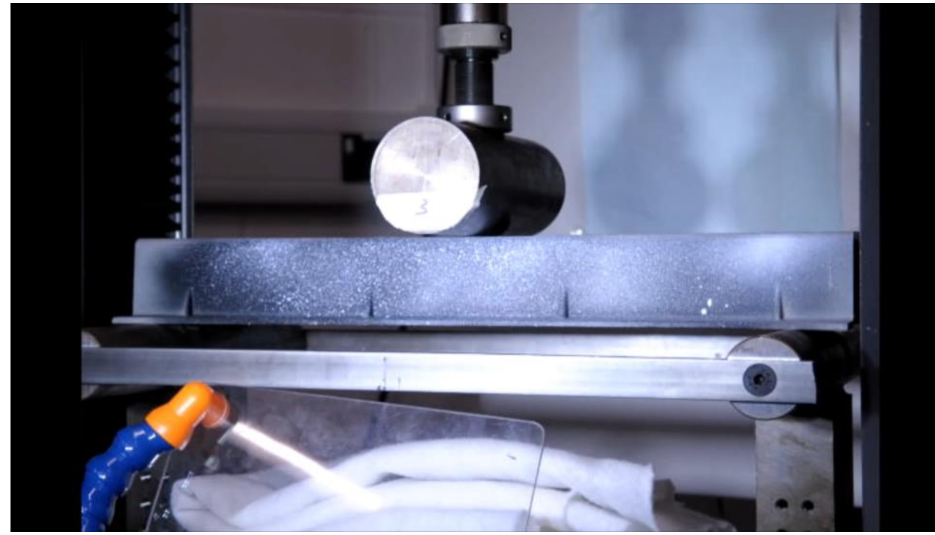
Results for lower elongation/higher yield (test run 2)

Results for higher elongation/lower yield (test run 1)

- Simulated data for both heat treatment approaches mapped and exported to LS-DYNA for extensive simulation work
- In both cases predicted performance was significantly higher than using fixed ‘text-book’ homogenous TYE figures
- Castings were subjected to independent 3-point load testing and results compared to simulation with good alignment
- Parts with higher ductility displaced further and absorbed more energy before plastic strain and failure. Parts with lower ductility but higher strength required more force to distort, but exhibited lower energy absorption and displacement to failure

3-point Load Testing

Test run 1 – elevated elongation, lower yield strength and UTS. Higher displacement and energy absorption



Test run 2 – lower elongation, higher yield strength and UTS. Lower displacement and energy absorption. Higher initial resistance to displacement

Summary:-

- The use of optimised topology can remove large amounts of material, but create heavy sections that are problematic to manufacture as a cast form.
- Sarginsons are able simulate the mechanical properties inherent with cast designs, and demonstrate the how they vary across the casting. Thicker sections will have lower properties. Further mass reduction in highly stressed areas will elevate casting strength and ductility, and may prove more successful as a design option.
- The varying TYE figures during the casting and heat treatment processes are captured, mapped, and exported in a practical banded form for informed further CAE analysis as part of a digital twin loop.
- Comprehensive testing and calibration has allowed for accurate data bases to be created for reliable data
- In conjunction with our conventional DFM analysis, Sarginsons can develop successful collaborative solutions for highly stressed cast vehicle designs.

Thank you

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