Low Pressure Casting-
Process and Design Principles

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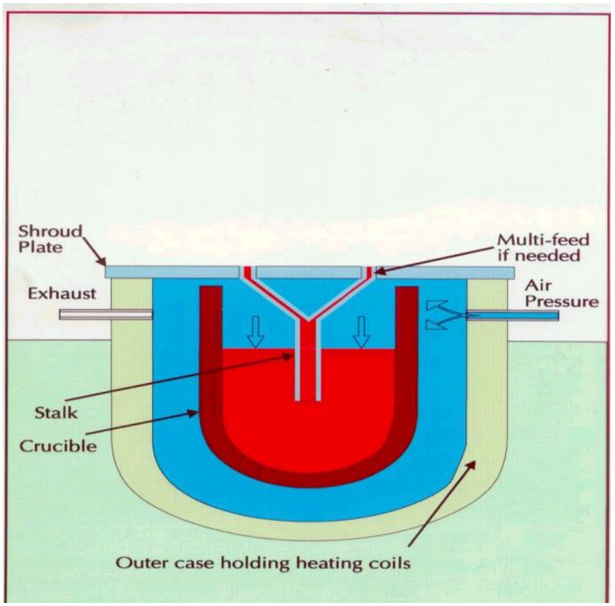
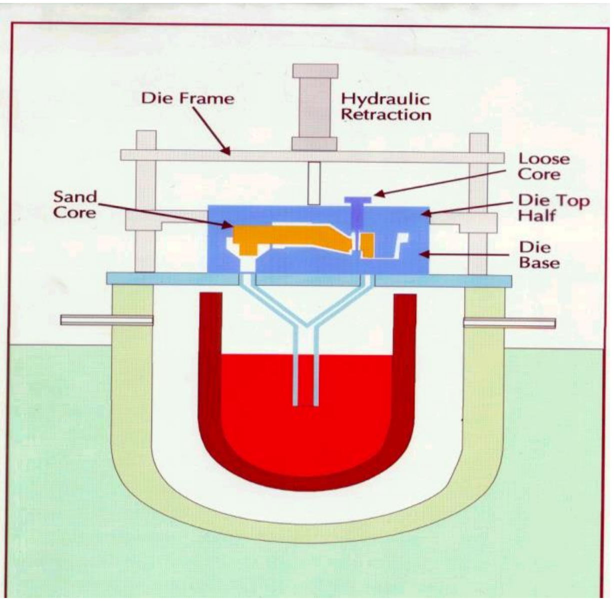
- LPDC process
- Shot cycles
- Advantages of the process
- Limitations
- Microstructural analysis
- Heat treatment
- Case Study 1
- Case study 2

What Is The Low Pressure Casting Process?

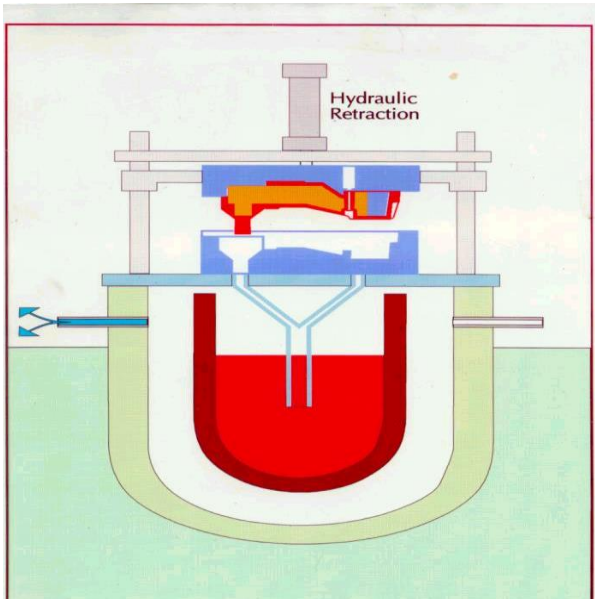
Low pressure die casting is a repetitive process where identical parts are cast by injecting molten metal under a low pressure of up to 1 bar into a metal die. The gas pressure holds the liquid material in the die until it solidifies back to the feed in-gate. The component is then allowed to harden within the tool prior to ejection. The process is then re-initiated. The basic process steps are similar to that of high pressure die casting.



Furnace Detail

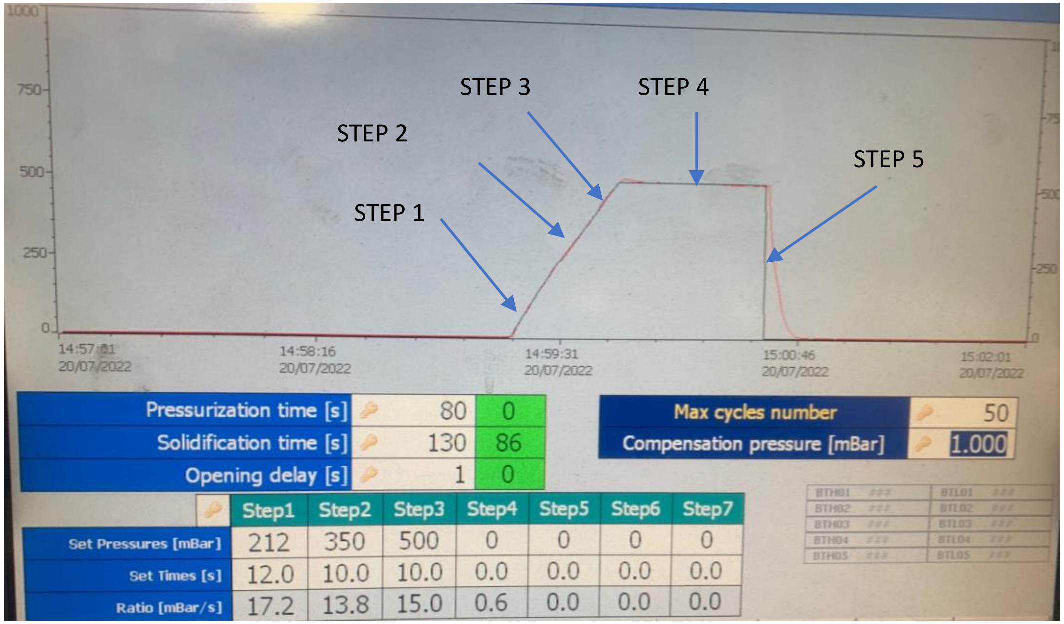


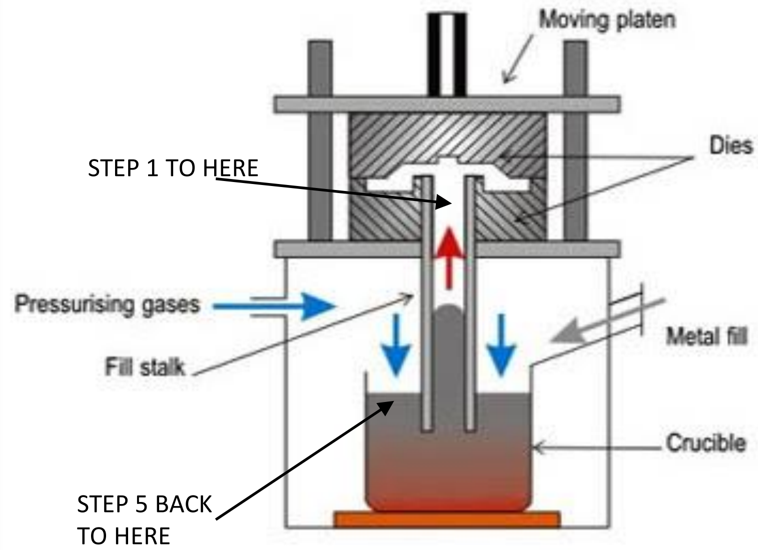
Tooling Layout



Completed Cycle

Understanding The Shot Cycle





- Step 1 – Raise. Air Pressure applied to raise molten aluminium steadily to just below die cavity. 1 mBar raises the metal 4mm.
- Step 2 – Fill. Pressure increased to fill the mould to the top of the cavity. This needs to undertaken steadily to avoid turbulence, but fast enough so that all casting details make well. The rate of fill is described as the flow rate.
- Step 3 – Intensification. Once mould is filled the pressure is raised to the maximum to 'squeeze' the casting helping to accelerate solidification, and reduce risk of internal voids. 1000mBar is possible, but factors such as use of sands cores, risk of flash usually prohibit this
- Step 4 – Hold. The pressure is maintained until the casting has solidified
- Step 5 – Drop. Pressure dropped to zero. The feed drops back down the riser tube into the holding furnace. Once the casting has hardened the die is opened and the casting ejected.

Advantages of the Low Pressure Process

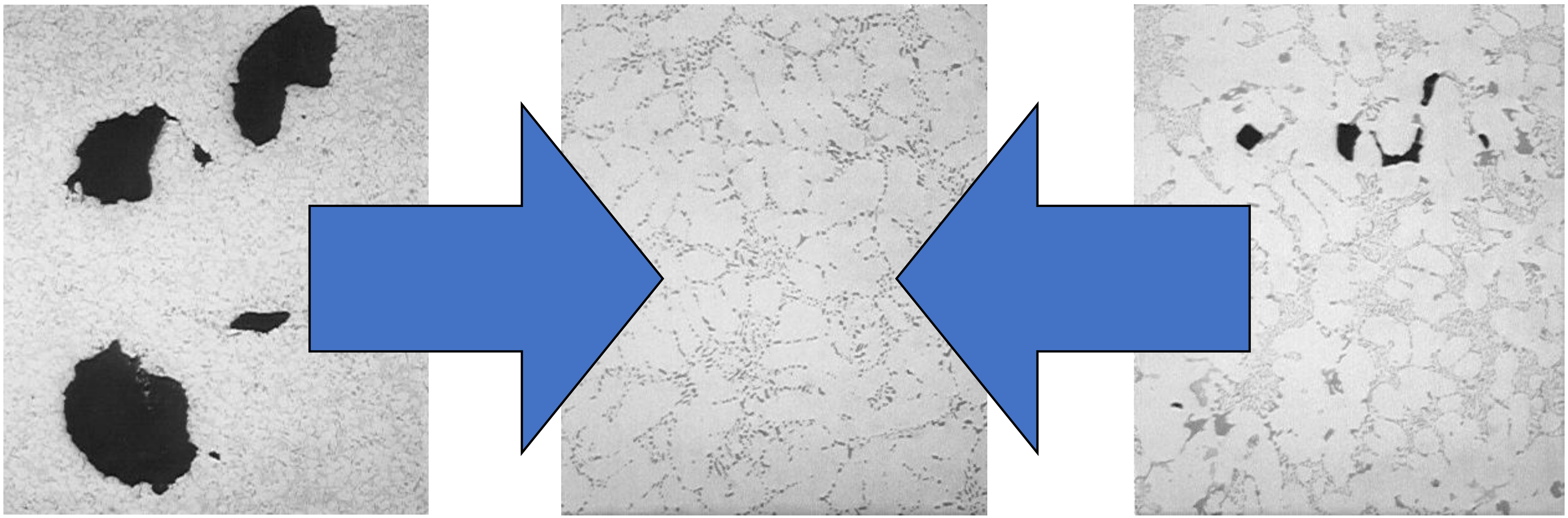
- Good die filling control/characteristics.
- Good thermal gradients.
- Good progressive solidification.
- High yield (90-98%).
- Good welding characteristics.
- Substantial component sizes and intricate component detail.
- Varied choice of alloys.
- Good pressure tightness.
- Minimal finishing requirements.
- Good heat treatment.
- Low Oxides / Inclusions via in-situ filtration at feed sprue.
- Ability to use complex internal lose cores.
- Stable and repeatable process.

Limitations of the Low Pressure Process

- Size of castings limited by machine size.
- Production rates not as high as with high pressure die casting.
- Surface finish not as fine as with high pressure die casting, but better than gravity die castings.
- Minimum wall section 3.0mm locally, 4.0mm on larger castings
- Feeding thick sections through thin sections not recommended.
- Economical quantity guide less than High pressure.

Microstructure across processes.

High Pressure | Low Pressure | Gravity



High Pressure

- Turbulent fill
- High oxide
- Rapid Solidification
- Low integrity
- Heat treatable (vacuum only)

Low Pressure

- Controlled non turbulent fill
- Low oxide
- Medium chill
- High integrity
- Heat treatable

Gravity

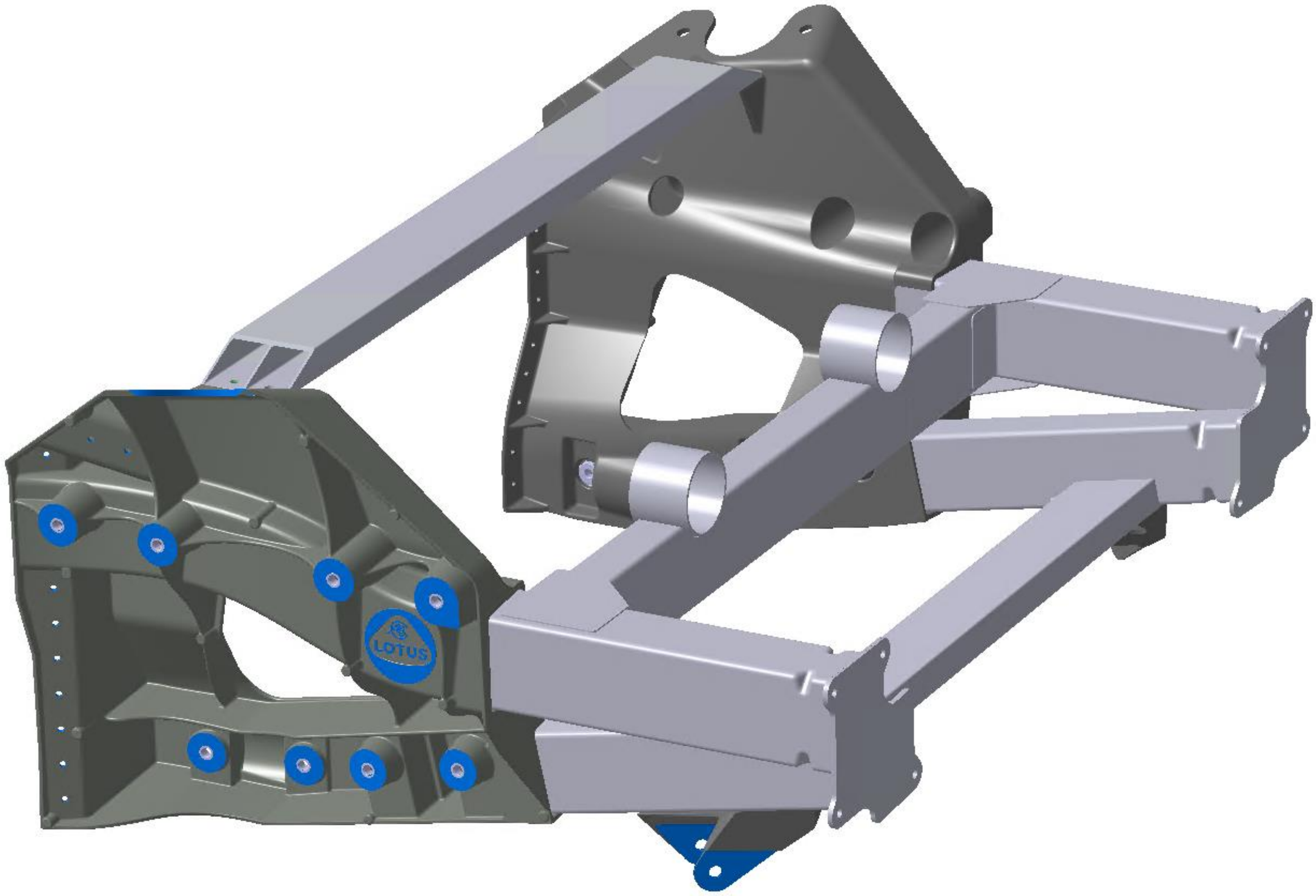
- Turbulent fill
- High oxide
- Medium chill
- Med integrity
- Heat treatable

Why can Low Pressure components be fully heat-treated but not High Pressure?

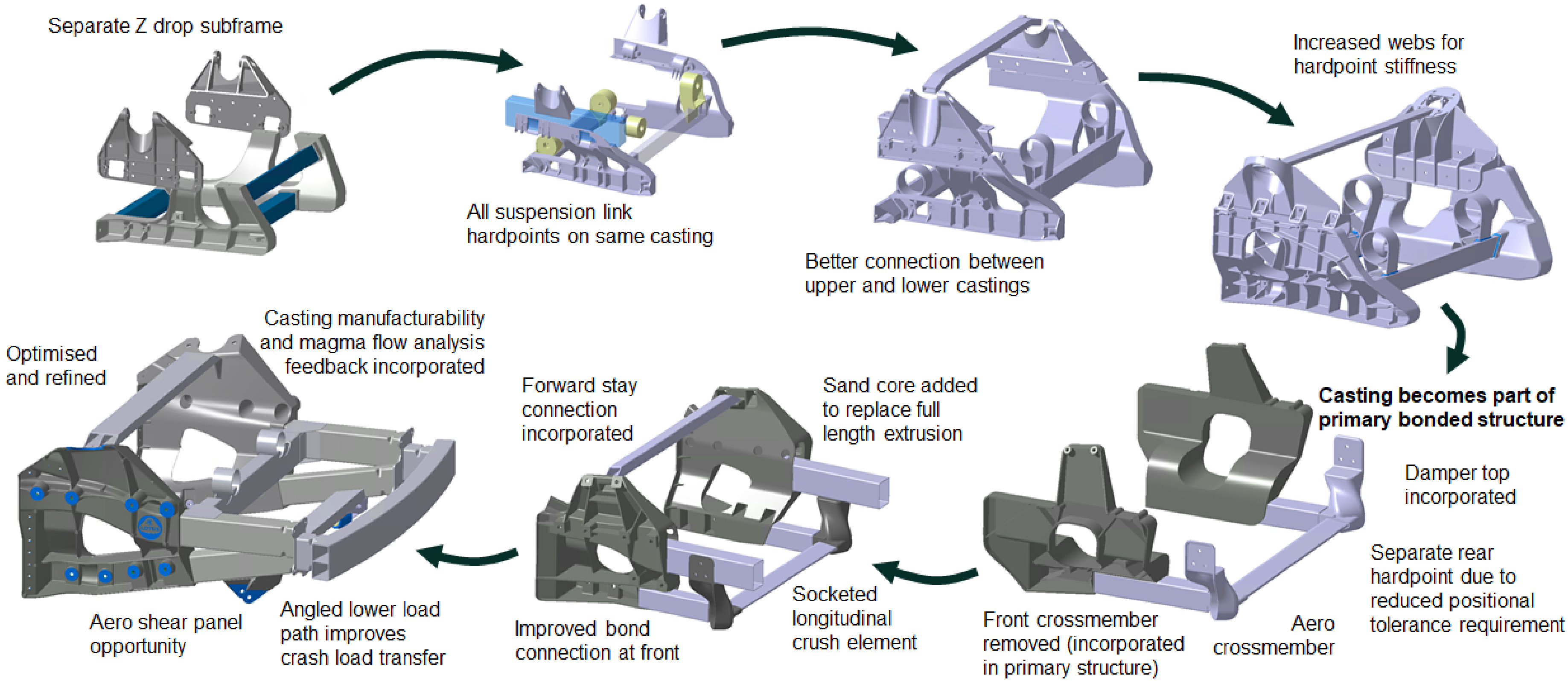
High pressure die castings are not solution treated and quenched in the same way as sand and low pressure permanent mould castings. Most commercially produced high pressure die castings contain bubbles of air, or of gas from die lubricants, which are small and finely dispersed. These gasses are entrapped in the metal as it is injected into the die and are retained as the casting solidifies. If these castings with entrapped gasses are solution heat treated the gas bubbles expand and, near the casting surface, cause pimples and distortion or cracking on the surface of the casting.

The most important characteristic to be considered in designing a stressed casting is the elastic limit, which defines the maximum stress which can be applied without causing deformation to the casting, and defines the practical working stress range under static loading.
For high loading stresses, it is necessary to use an alloy in a fully heat treated condition. For medium proof stresses an alloy which can be precipitation treated.

Case Study 1 – BEV Subframe



Collaboration from concept

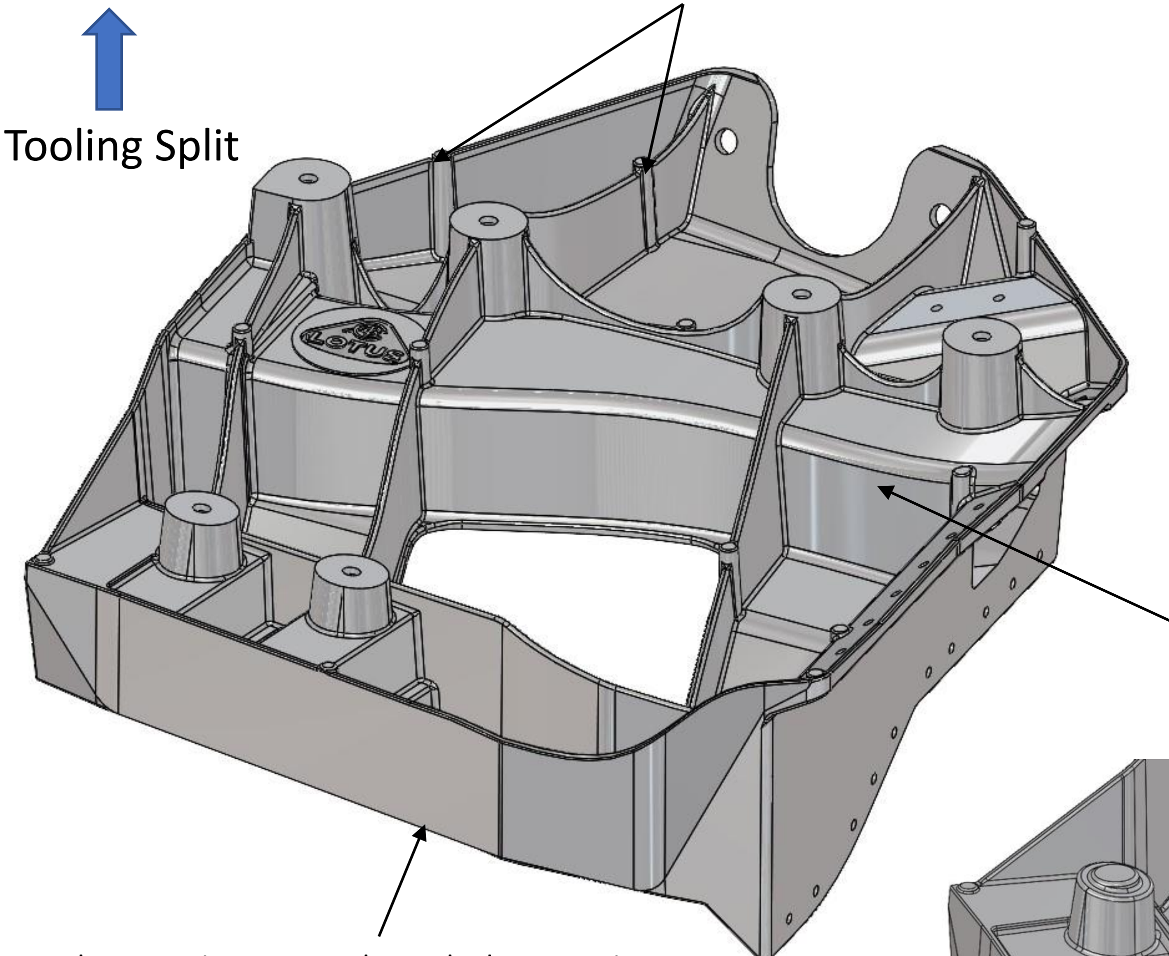


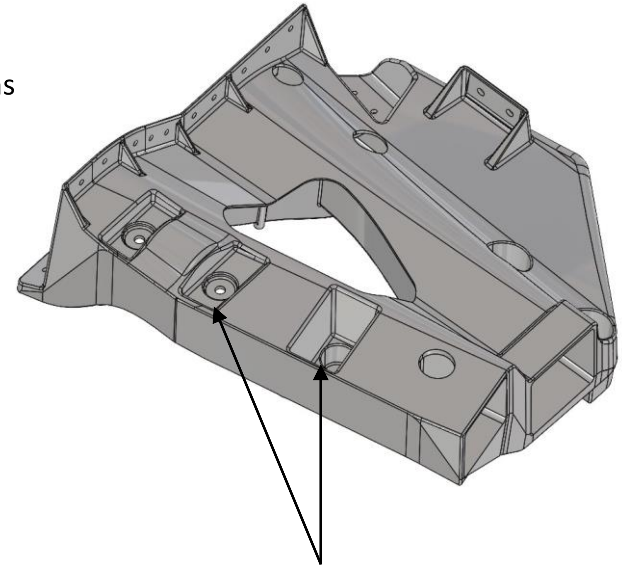
- At all phases of development, work with the manufacturer
- Concept feasibility is key and will drive design. Form follows function applies to manufacturability
- Consideration for casting process and feasibility, post machining and assembly possibilities are all critical to avoid costly re-engineering further down the line

Feed and extraction

Tooling Split

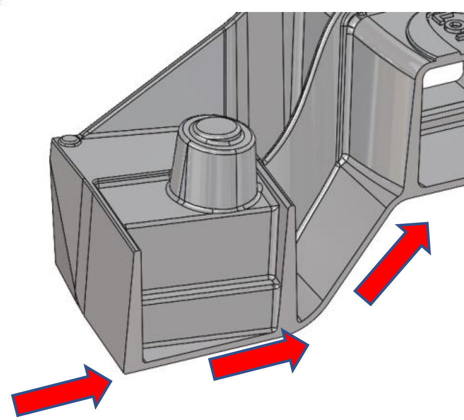
Consider regularly spaced ejector bosses. 8mm min size ejector pin. Try to use existing geometry to imbed boss to aid feeding a minimise casting mass. Avoid ejector positions on flat walls – casting can distort on ejection





Keep features that may cause grip in a LP die base to a practical minimum. Increasing draft may help extraction from the tool

This side of the design has more features so will logically be in the upper part of the tool. The metal flow will generally be upper wards, which is better for good casting integrity.



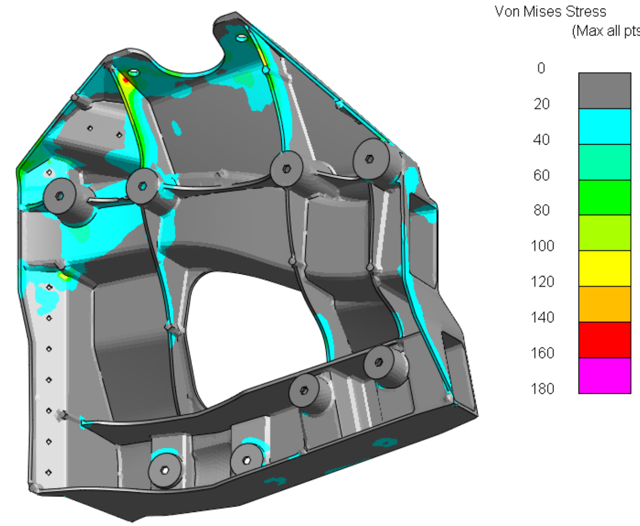
Metal entry point wants to be at the lowest point possible. Avoid metal drop when it enters the mould – think about a smooth path as possible for the die filling to avoid turbulence.

Metal likes to climb in LP casting. Design for gating should reflect this. Avoid large flat areas, or drops.

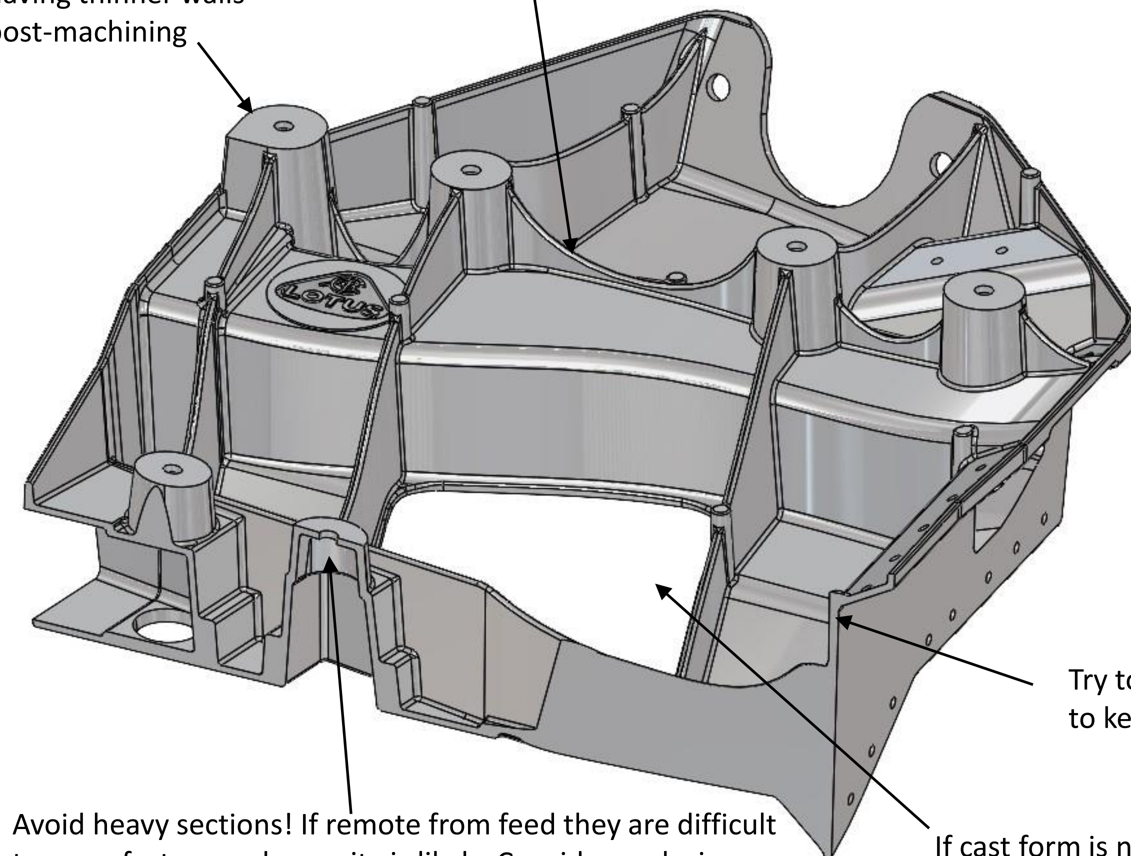
Light weighting and thick section avoidance

Machining stock. 1.5mm minimum for Low Pressure casting. This may create thick walls so consider having thinner walls post-machining

Sculpt rib features away from hard points and areas of high stress.



It is not always necessary to add mass to areas of high stress. Thinner walls will have higher mechanical properties that may offset the CAE concern. Use simulated variable TYE mapping to verify.



Try to match internal draft to external to keep nominal wall sections

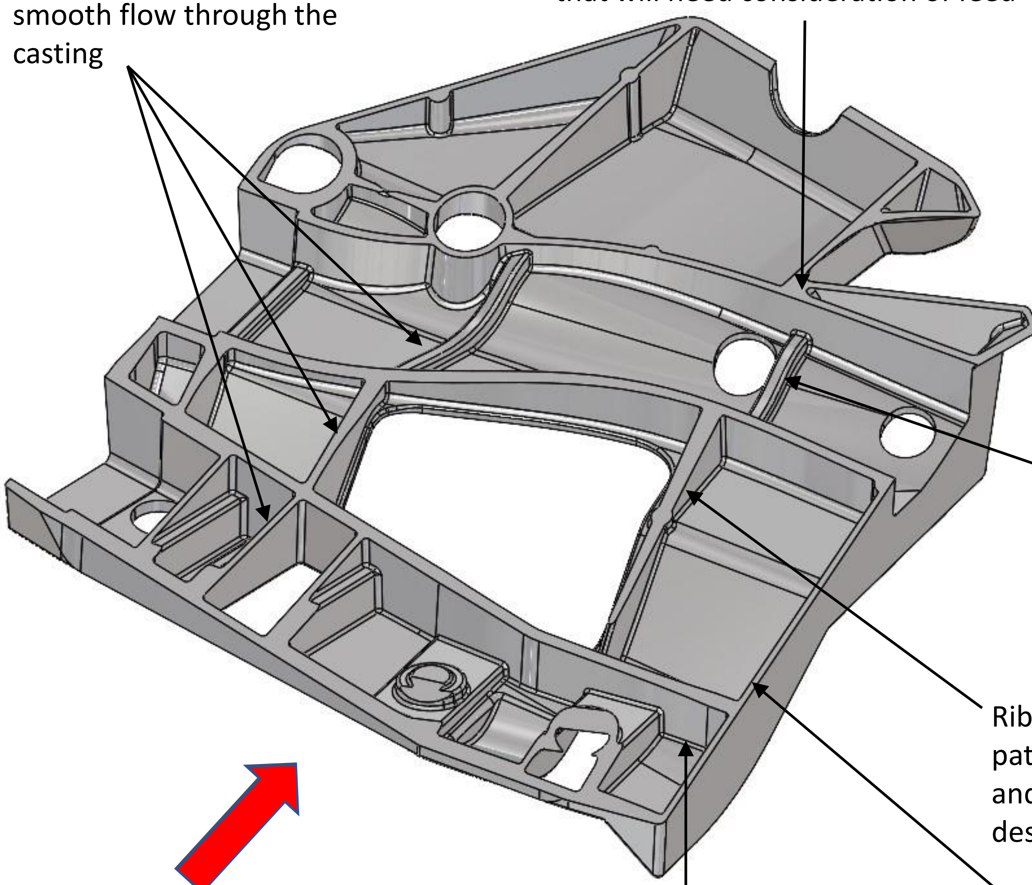
Avoid heavy sections! If remote from feed they are difficult to manufacture and porosity is likely. Consider replacing tapped holes (and boss depth) with steel inserts such as Spacnuts which can fit into nominal wall sections

If cast form is not required structurally, then remove it

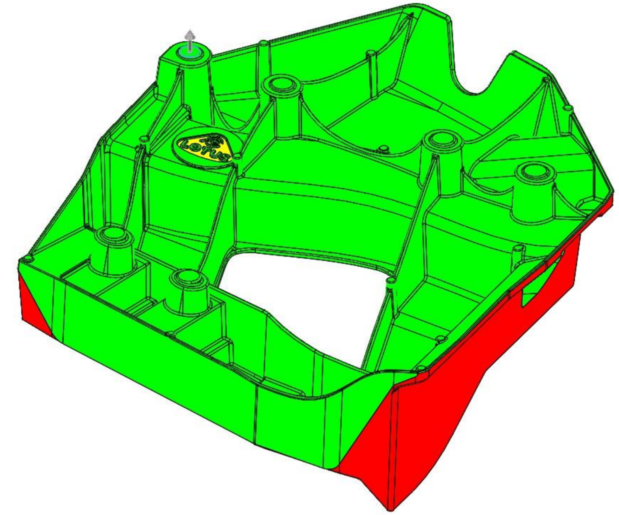
Internal Considerations And Draft

Try to align rib structures where possible to keep smooth flow through the casting

Be mindful of nodal points – particularly with the impact of draft. They can create hidden thick sections that will need consideration of feed



Check draft throughout design. 3 degrees general minimum (can be locally 2 degrees) Higher draft may be required on the underside to aid extraction



Where nominal wall sections are encountered it may be necessary to add internal feeder ribs to avoid porosity. If so, can they be used for structural integrity?

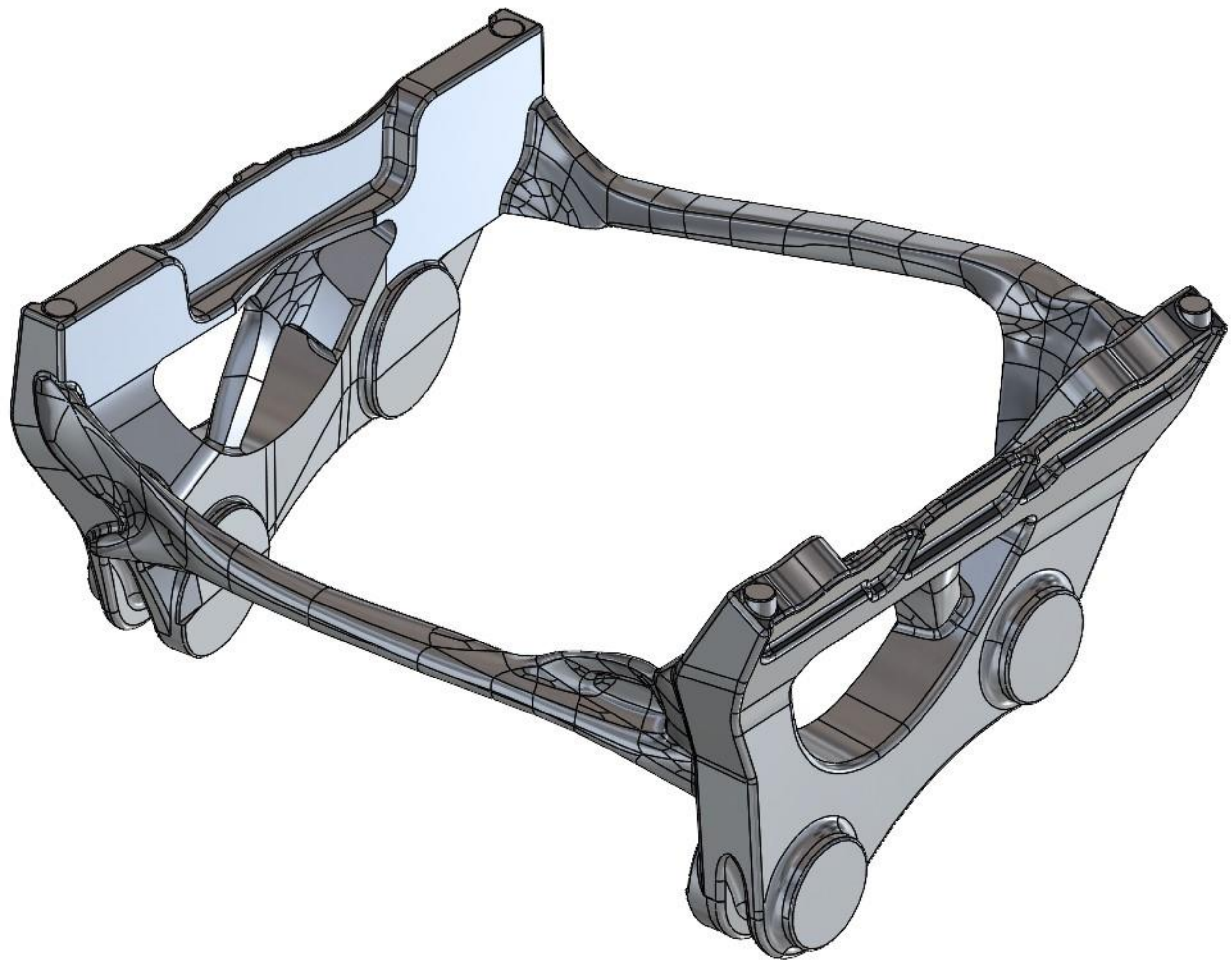
Rib structures can be used as feed paths for tackling heavier sections and aiding flow. Ribs can be designed with this in mind.

Minimum wall section 4mm on large cast forms. Sections will need to be thicker for main feed paths

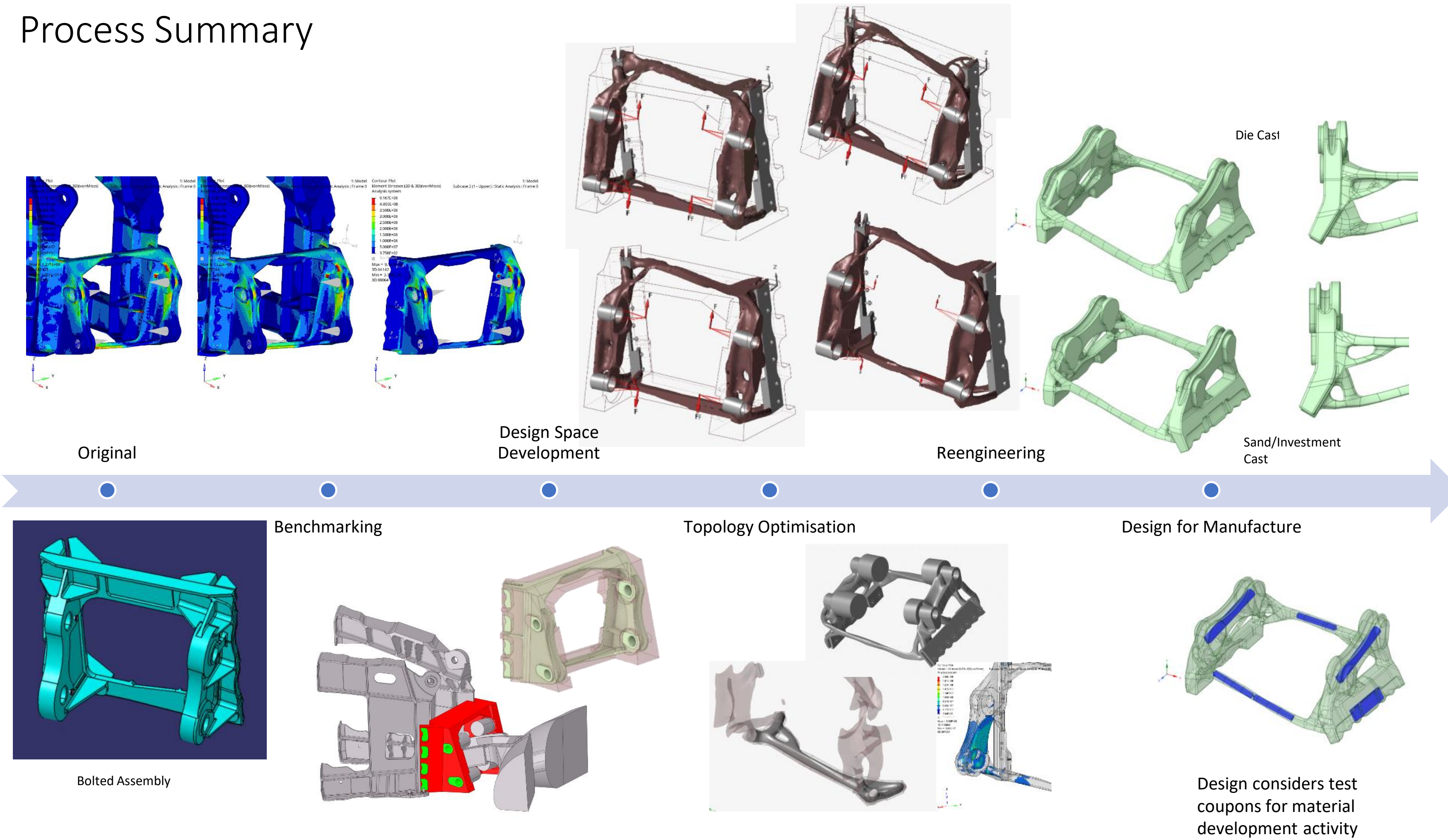
Metal Entry

Internal fillet – min 3mm. Avoids tooling hot spots, hot tearing on castings, and shortened tooling life

Case Study 2 – Optimised Topology Low Pressure Solution

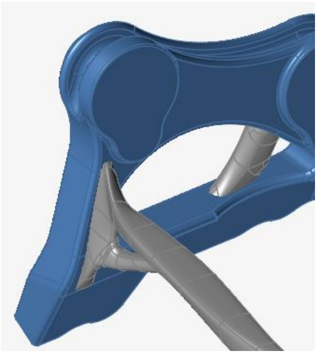


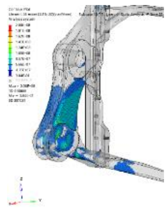
Process Summary

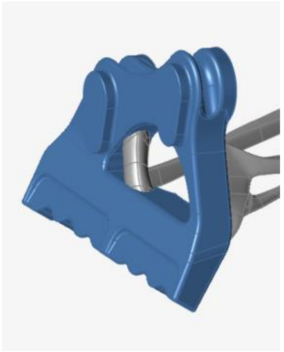


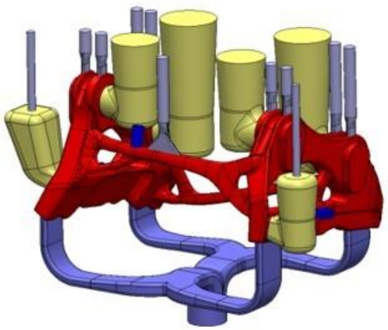
Aerospace Wing Roller Assembly fully reconsidered as a Low Pressure single piece cast form.

Development for Sand/Investment Cast

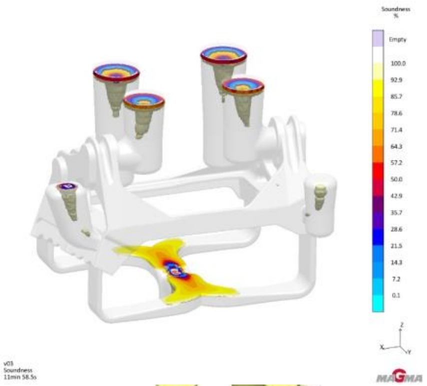




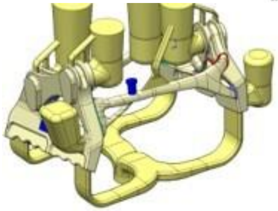




Sand



Investment

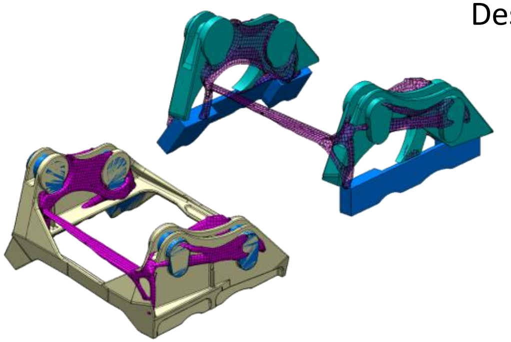


Optimisation mapping

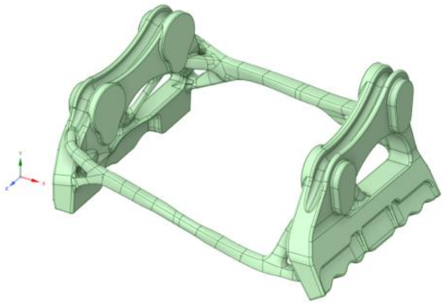
Design for manufacture

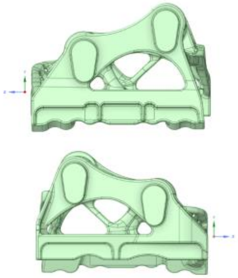
Design development

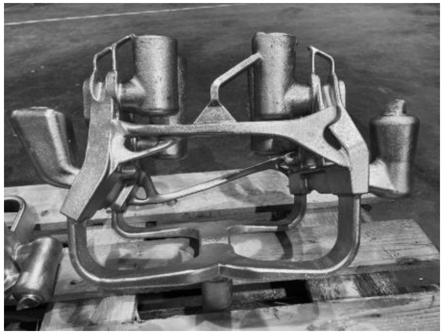
Process specific tooling



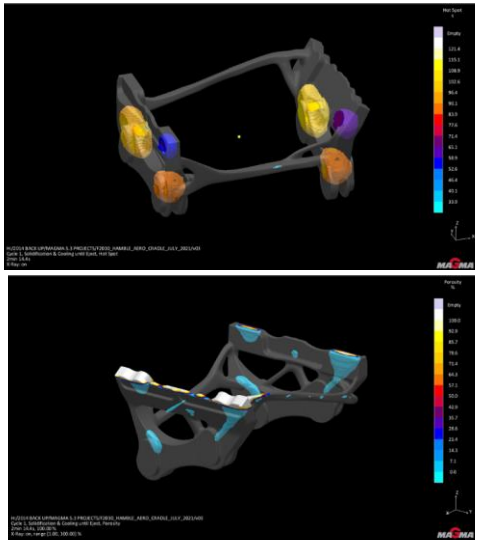
End pieces extracted and design locked – compatible with test coupons

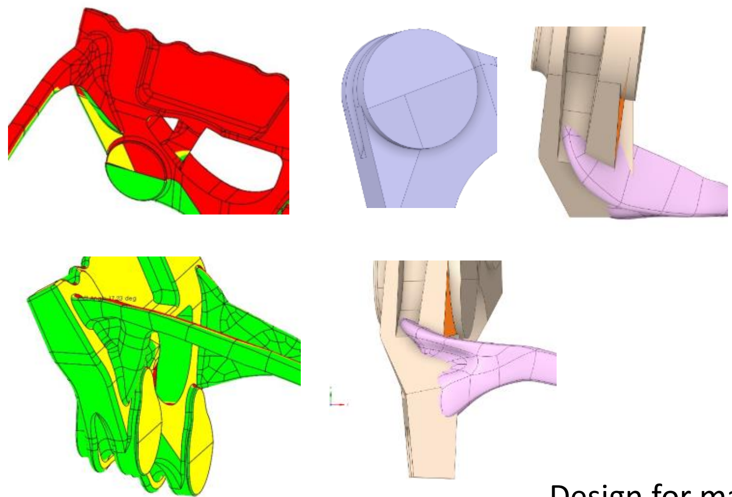


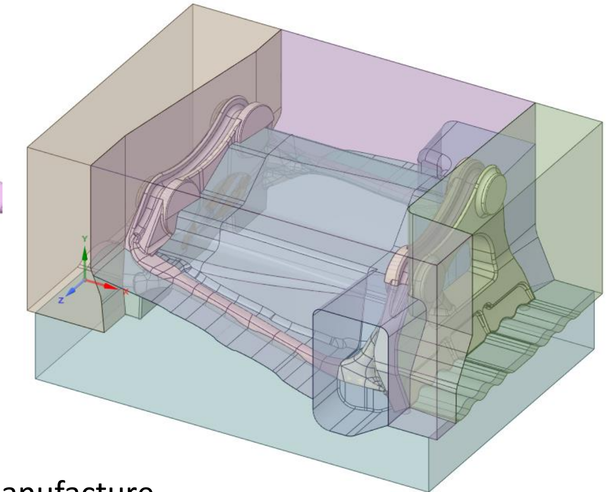




Development for Low Pressure Die Cast





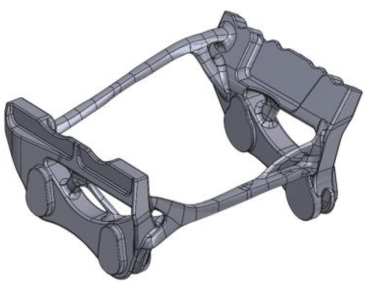


Suitability of design

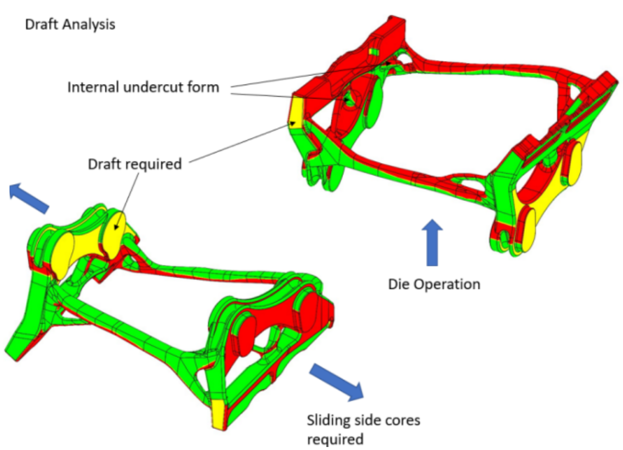
Design for manufacture

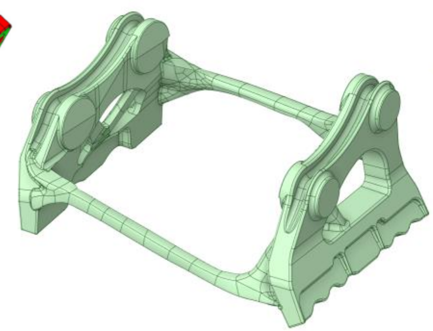
Design development

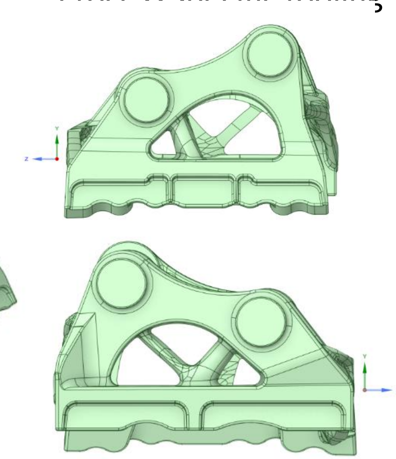
Process specific tooling



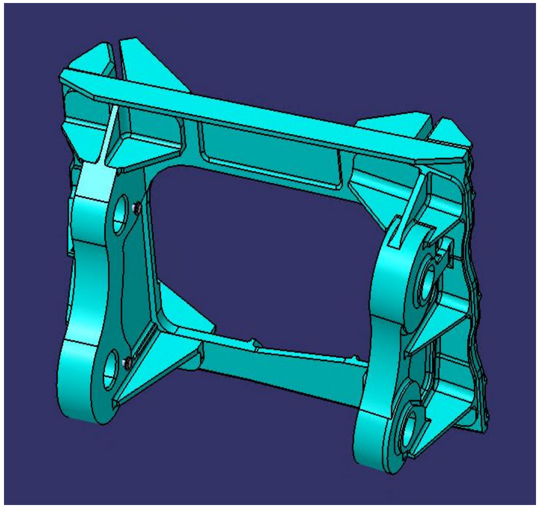
Main form carried over from sand cast design for test coupon parity – adjustments necessary for DfM



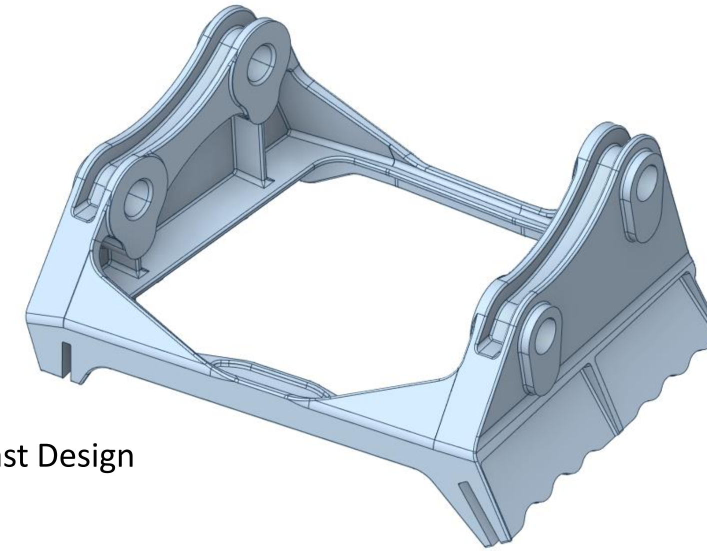




Design Comparison

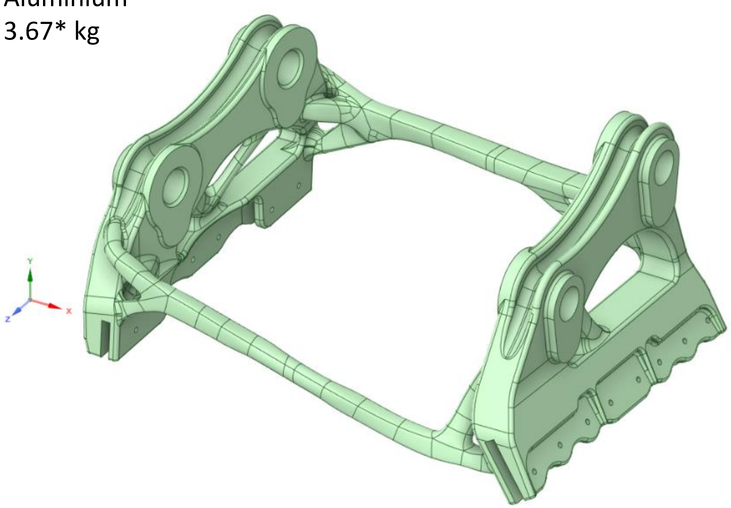


Original Design
Assembly of multiple parts
Aluminium
7.02 kg

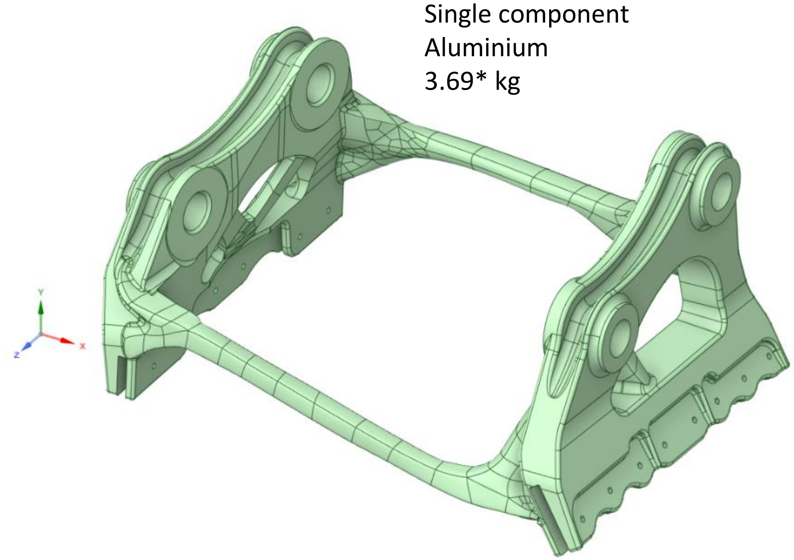


Consolidated Cast Design
Single component
Titanium
5.34 kg

Sand/Investment Cast
Single component
Aluminium
3.67* kg



Low Pressure Die Cast
Single component
Aluminium
3.69* kg

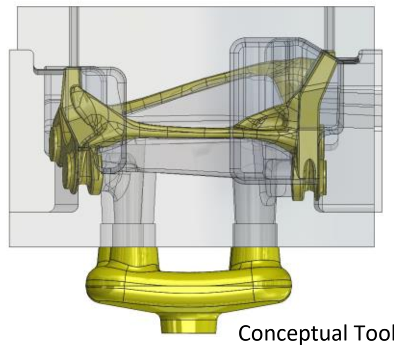


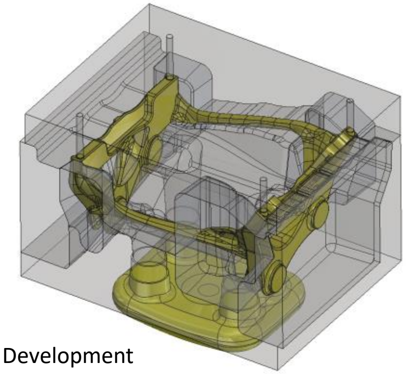
Low Pressure Casting Development

Foundry[2030]

Al
Aluminium

Completed Low Pressure Design

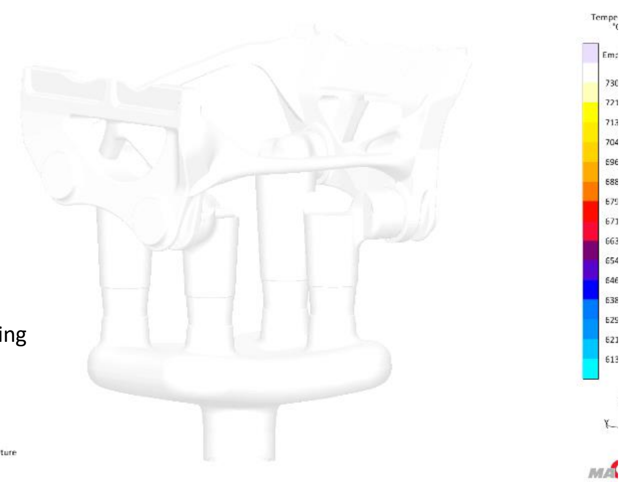


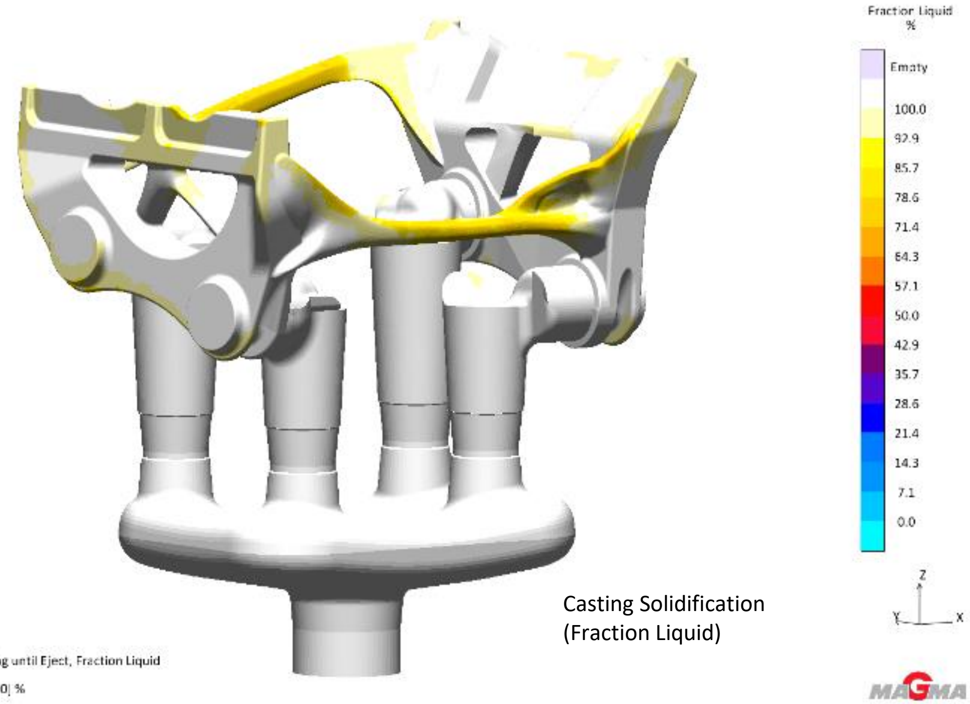


Conceptual Tooling Development

Completed Casting Feed Design

Mould Filling

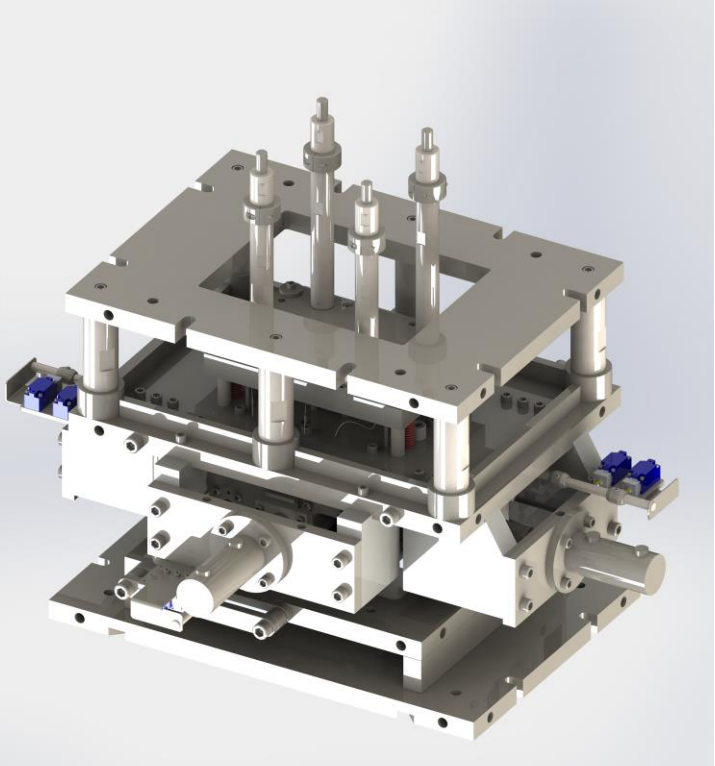




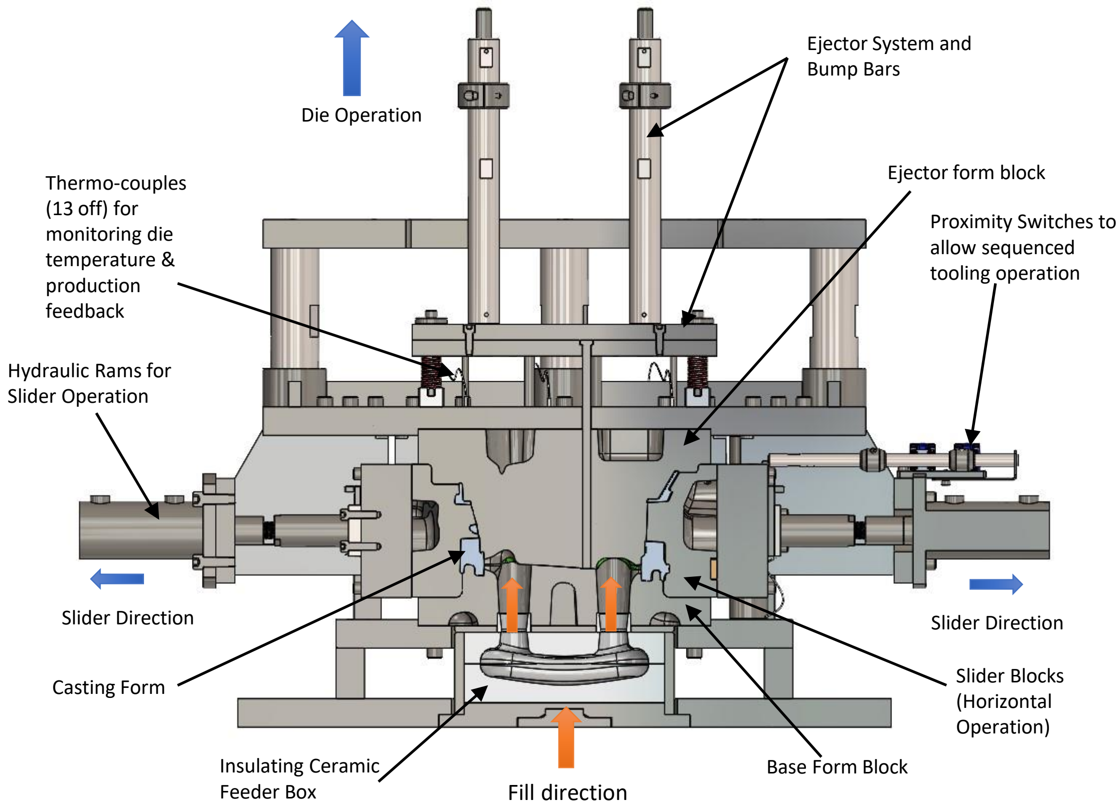
Casting Solidification
(Fraction Liquid)

Critical to the success of this cast form was uniform fill, and progressive solidification to feed

Tooling Design



Completed Tool Design



Full consideration for manufacturability throughout the project enabled a seamless tooling design and manufacture, and minimised casting development

Thank you

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