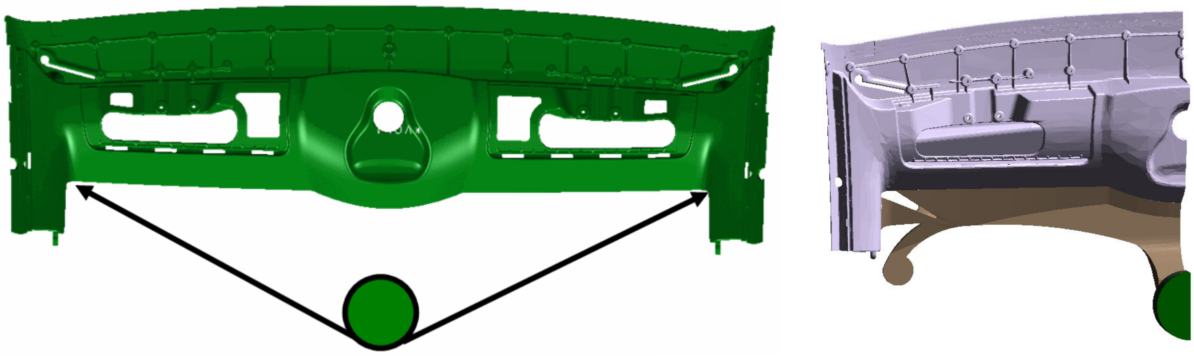
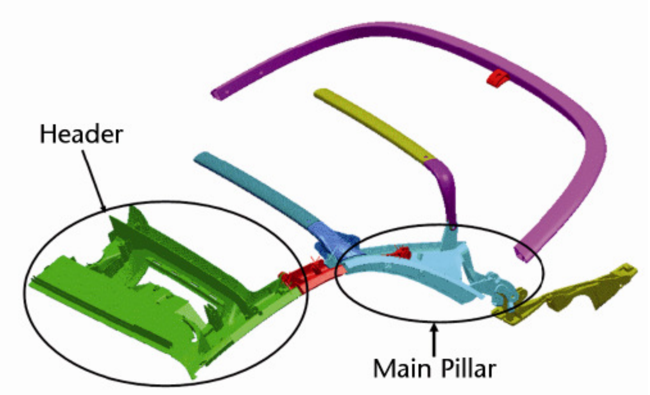
Optimizing the Production of Structural Components

Structural components made of aluminum, magnesium, or zinc are crash-relevant and load-bearing components, and in many cases have visible surface areas. Consequently, the requirements on rigidity and extensibility are very high; the castings must be free of porosities, blisters, and weld marks. Additionally, the often required heat treatment demands high quality castings. An optimal die filling process is very important for these thin walled and large die casting components, e.g. the header or the main pillar of the Chrysler Crossfire convertible top, casted by Alcoa Germany for the Karmann GmbH.



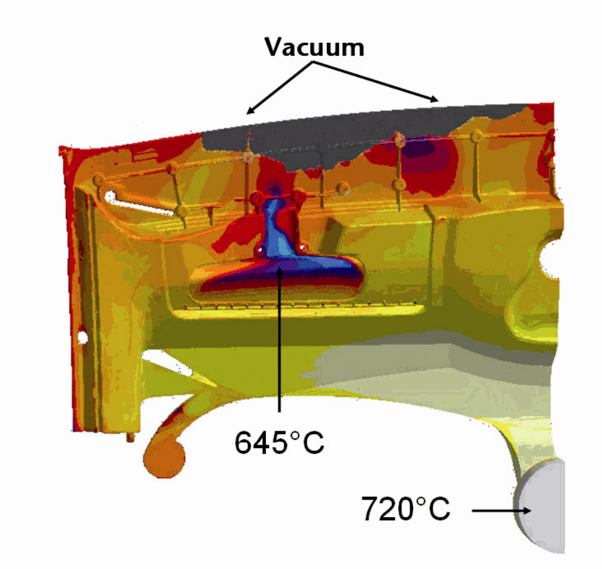


The "header" of the Chrysler Crossfire convertible top, dimensions: 1,250mm x 300mm, has a specific wall thickness of 2mm. The ingate design (left) is the basis for the CAD construction of the runner (right, viewed from the ingate position).

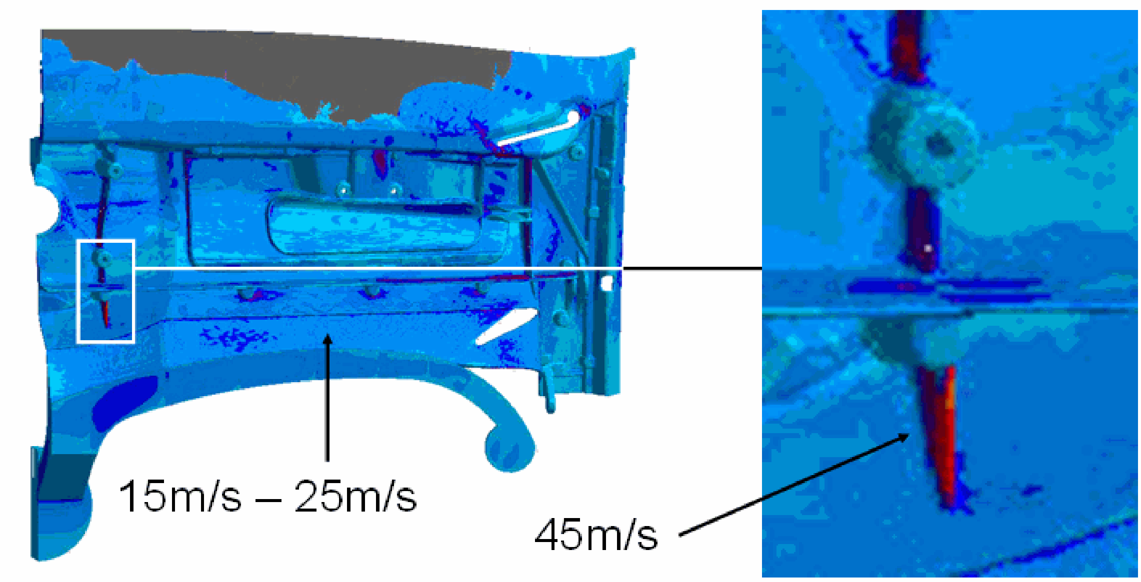
Evaluating the Die Filling Process of Casting "Header"

The component specifications (using a heat treated AlSi9Mg alloy: Rp 0,2 min. 120MPa; Rm min. 180MPa; A5 min. 12%; visible areas paintable) require the casting to be free of air entrapments, solidification porosities, and weld marks. The required tool lifetime of at least 50,000 shots demands the melt not to exceed the critical flow velocity. Casting simulation is an excellent method to describe exactly these criteria.

The calculated temperatures of the melt during die filling allow the evaluation of the tendency for weld marks to develop. Based on the die filling characteristics, the best positions for overflows and vacuum connections can be determined.
The calculated flow velocities allow the evaluation of the tool load, in particular regarding possible erosions due to exceeded flow velocities.

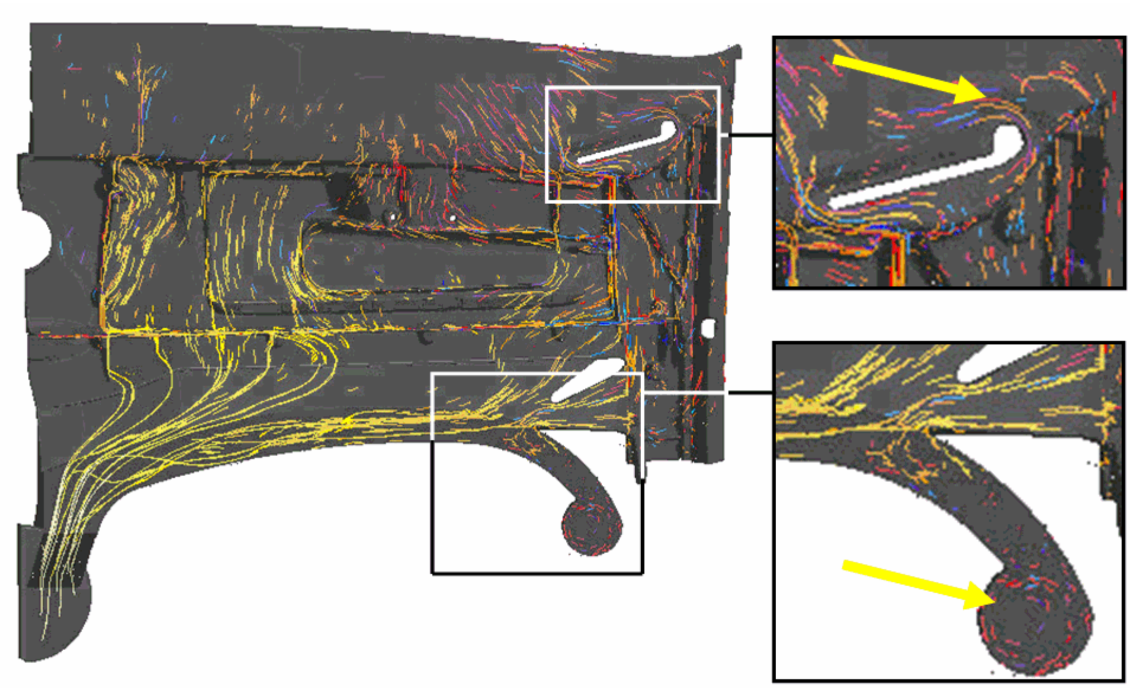


The temperatures during die filling are mainly uncritical.
The total flow profile indicates the best positions for a vacuum connection.



The flow velocity (between 15m/s and 25m/s) is uncritical in most parts of the die cavity. The highlighted rib shows high flow velocities during the whole die filling process, indicating the requirement to change the ingate near this area.

One of the main reasons for gas porosities are turbulences during die filling when gas mixes with the melt. These turbulences can be detected and evaluated via virtual particles that follow the path of the melt, showing a visible “trace” on the screen.

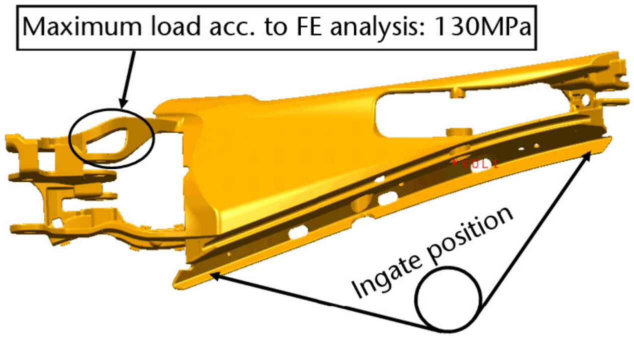


Turbulences often occur in runners, heavy sections, or behind molten metal breakthroughs. The turbulences shown in these figures are either on purpose (shock absorber, lower right figure), or not critical (behind a breakthrough, upper right figure).

The layout of the high pressure casting die was designed considering the filling simulation results. As a consequence, ideal casting results have been obtained from the very beginning of this project.

Optimizing the Solidification Process of Casting "Main Pillar"

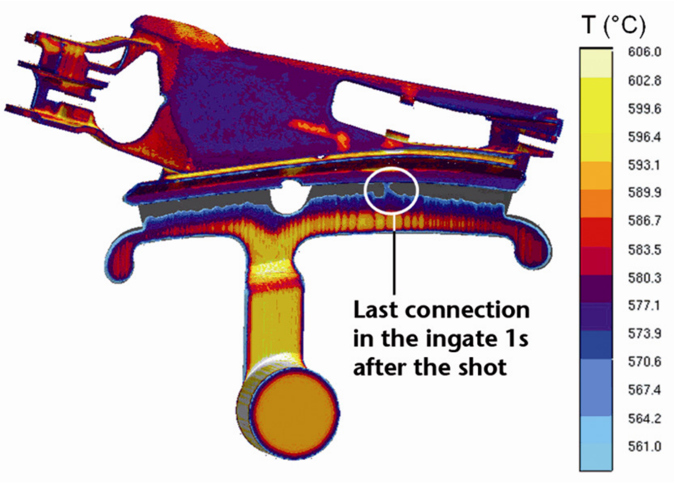
Most structural components have small heavy sections only in areas where parts are planned to be mounted. The required rigidity of the components is usually obtained by ribbings. The "main pillar" of the cabriolet roof is exposed to high loads. Hence, the cross sections are partly solid and have a specific wall thickness of up to 10mm. The component specifications (using a heat treated AlSi9Mg alloy: Rp 0,2 min. 140MPa; Rm min. 180MPa; A5 min. 8%; visible areas paintable) need to be met, especially in areas that are exposed to highest loads according to load analyses.



The "main pillar" is a compact structural component exposed to high loads.

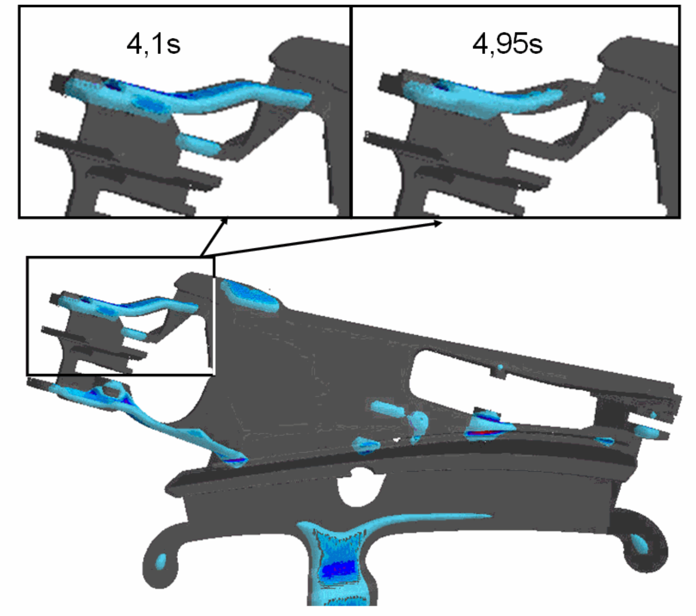
Hence, certain microstructures are necessary in order to meet the required mechanical properties in these areas. Additionally, these areas must be free of porosities; which is initially assumed by the designer and also by all FE calculations regarding the component layout.

For the evaluation of the solidification process one can analyze the isotherm where melt flow is obstructed, also in the final pressure phase. The normally very thin ingates solidify 1s after the shot already. On the other hand, the critical, highly loaded crosspieces solidify after 5s to 6s only. Porosities will consequently develop if the solidification is not directional in these areas.

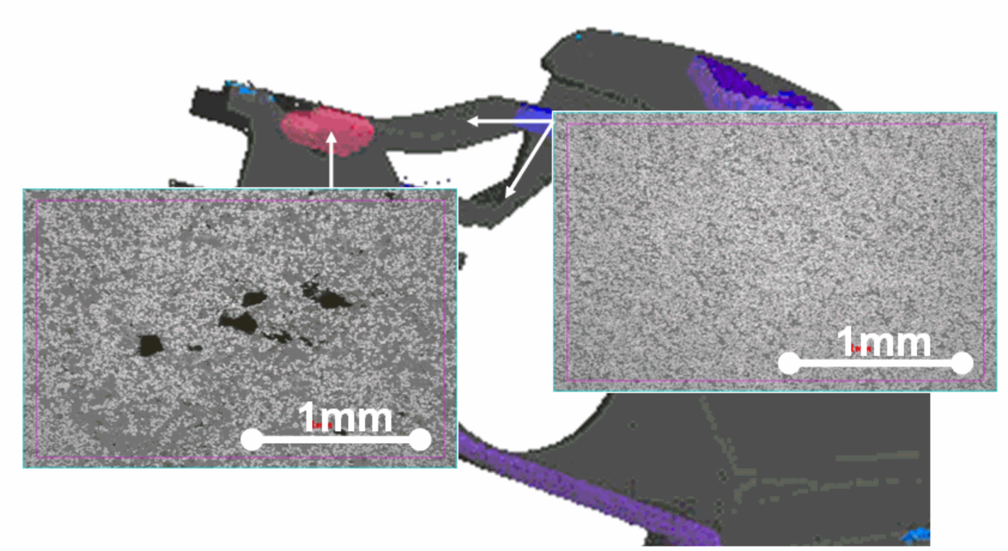


Temperature distribution in the casting about 1s after the shot. The solidified areas in the ingate are hidden. As of this point in time further feeding is not possible.

The simulation results recommend a strong and specific spot cooling of the tool, assisting the directional solidification via the crosspieces towards the not so highly loaded areas of the casting. This measure has proven to be effective; the casting has been free of porosities in the highly loaded areas as of the first production series already.



A certain spot cooling in the tool can trigger the directional solidification in the highly loaded crosspiece. The figures show the residual melt at 4.1s and 4.95s after the shot. The hotspot that solidifies last is located in the not so highly loaded area of the casting.



The porosity criterion confirms that the highly loaded crosspiece does not contain porosities, which agrees with the expectation. The calculated distribution of porosities corresponds well with the porosities that were found in the real casting.

The examples above explain the typical questions regarding the layout of high pressure casting tools for the production of structural components that can be answered with the help of casting simulation. There is obviously the possibility to test various variants of the casting system by using the "trial and error" method. However, this is far more time consuming than using simulation as a basis for the optimization of the casting process. Moreover, the "trial and error" method is very expensive. From the economic point of view, an additional trial production including tool changes, tests, reduced tool lifetime, transport, machine hours, personnel costs, and melting costs, is always more expensive than using simulation for process optimization.