Apply simulation application optimize production process for car industry

Phan Van Tong
Department of Industrial Management
International University - Vietnam
Tel: (+84) 1647308350, Email: pvtong@hcmiu.edu.vn

Abstract. This The paper discusses the role of process simulation in the automotive industry. Real-world applications of simulation in the die-casting plant car engine. Uses of simulation during the different phases of the process such as flow distribution, porosity, solidification, stress analysis. The result of this simulation will confirm that the finished components of engine block whether can perform in high efficiency operation or not. The limitation of simulation application is accuracy which depend on the experience of engineers and computer's capacity.

Keywords: simulation, optimization, die-casting, production, stress analysis

1. INTRODUCTION

The high pressure die-cast process is used to produce mass production for parts from aluminum, magnesium, copper and zinc. Parts produced by this method conform accurately to the 3D model, die size, have complex mechanical shapes, and are saving money. This process also enables production of parts with low tolerance as small as .001". This production process thus has a wide range of applications and is used to make millions of parts in automobile industries. Different parameters influence the production of the accepted parts which are produced by high-pressure die casting method by transferred the molten metal from the hot furnace into the shot sleeve, then the piston injected hot metal into the gate at high pressure.

Then metal will flow thru the die and forming the complexity of the parts shape, liquid metal also filled up the overflows and air entrapment will be escape thru the thin vents which were stepped down from .010" 005", 001". Of the insert die block, master die and then outside.

In this research the effect of initial shot speed, gating, atomized flow, model shape and features, minimum and maximum thickness of the real CAD model, die design, filling time, cycle time, air entrapment, solidification time, preheat die temperature will be studied in relation of part defects. Also some sample parts were used software simulation to predict the results.

Statement of the problem

When a new part is designed for the first time, it may have a very complex shape depending on the design constraints. These constraints may be due to lack of space, the need for an aerodynamic shape, or a set of performance parameters.. The complexity of a part produced in the die-cast process is an important factor in its manufacture. Increased complexity can lead to an increase in the number and types of manufacturing defects. Die-cast design and parameters of the production conditions must therefore be optimized to minimize manufacturing defects. Runner position, gating location and number of overflows and water cooling lines are among the most important design parameters, and melting molten temperature, alloy composition and mold surface temperature are among the influential production parameters.

2. Literature review

Theories of solidification and Types of defects in the HPDC process This section discusses theory of solidification and formation of shrinkage porosity, including both classical and non-classical nucleation and different nucleation models. It also discusses the different types of defects in the HPDC process. Finally, ProCast, MAGMAsoft 3D FLOW softwares are used in the simulation casting process to investigate methods and equations that describe the process. 1.1 Microstructure of solidification In casting of Aluminum-silicon alloy, Si is considered as the main alloying element in aluminum-silicon alloy casting. Solidification behavior of this alloy can be explained by the AlSi binary phase diagram (Figure 3).

3. Applications and Experiments

Many larger foundries to use computational optimization software. There are 27 defects are essential to allow the optimization of casting systems for component integrity. Optimization can only occur if “the right optimization criteria to formulate the objective functions are available" [2]. Therefore, to optimize a casting system for casting integrity, knowledge of defect formation, distribution and quantity is required. This is the challenge facing modellers. As these optimization software such as MAGMAfrontier [3] become more user friendly and the performance of computer hardware increases the requirement for accurate and quantitative defect assessment criteria will become even more user friendly.

Enmeshment

The complete 3D-model, which consists of the raw casting, in-gates, overflows and/or vacuum channels, as well as die segments including cooling/heating lines need to be enmeshed for the mathematical calculation. Depen ding on the operation method, these meshes are exclusiv ely automatically generated (finite volume method), or au tomatically generated and manually reworked (finite elem ents method). The completion of the 3Dmodels and the enmeshment are known as ’pre-processing’

Evaluation of the results

Postprocessors’ prepare the results in coloured graphics or movies that visualize and document the calculated operations during die filling, solidification, formation of microstructure and properties, as well as the formation of residual stress and distortion. State-of-the-art simulation programs can do automatic or semi-automatic evaluation of results in various iterations at the same time for easy comparison. Engineering time is most valuable spent when good post-processing is applied and decision making is administrated based on results achieved.

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A sample of Meshing model

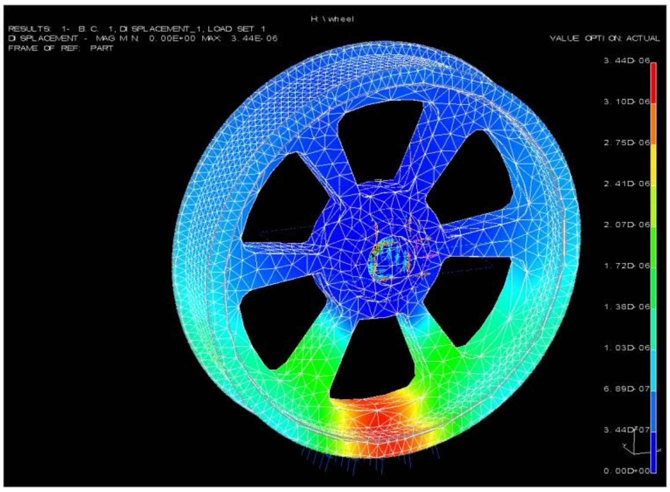


Figure 1

Simulation of the entire casting process

The casting filling is often seen as the most critical and for the casting result the most influential sub-process in high pressure die casting. Apart from some exceptions that require a slow die filling (like infiltration of inserts made of ceramic fibres) the ingate velocities lie in a range between 30 and 140 m/s and the filling times are between 20 and 200 ms. These conditions lead to a turbulent flow, where, due to the geometries of the castings, the melt fronts are nearly always uneven. The flow consists of at least two phases (liquid and gas) and in some cases additionally of a solid phase during the die filling.

State-of-the-art simulation technologies provide a magnitude of results files for filling that allow designers, casting engineers and all people engaged in the casting process and up to top management to make sound decisions for improvements of bottom lines. In the following various comprehensive result files are described hereafter

Filling Results and flow in the gating system:

Due to various reasons, the gating design is very important in high pressure die casting.

Regarding the design of the gate, the following needs to be taken into consideration:

Turbulences in the melt should be reduced in order to avoid entrapped gas in the casting

The melt flow through the gate needs to be timed in order to allow the controlled merging of the melt fronts

The flow velocities need to be consistent, also when using fan ingates

The desired direction of the melt flow into the cavity needs to be met

The die filling simulation based on an existing design of the gating system allows to evaluate all these problems, and thus to decide if the design is usable or needs to be modified

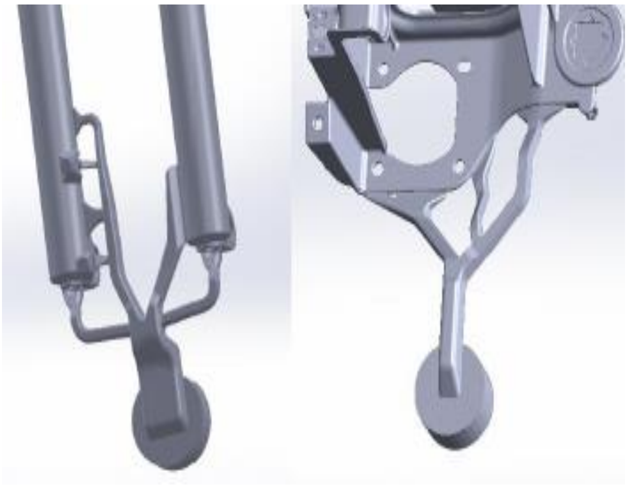


Figure 2: Different Gating systems for Aluminum casting parts

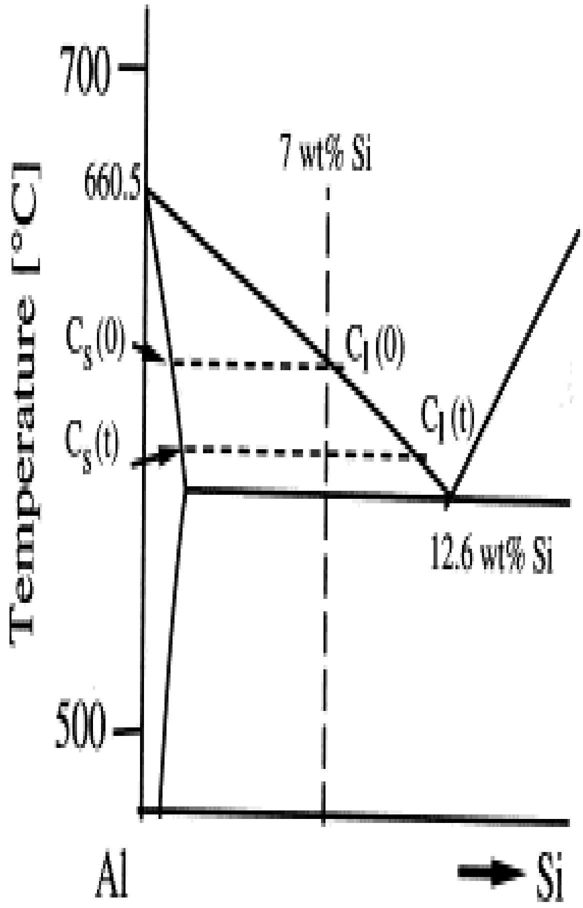
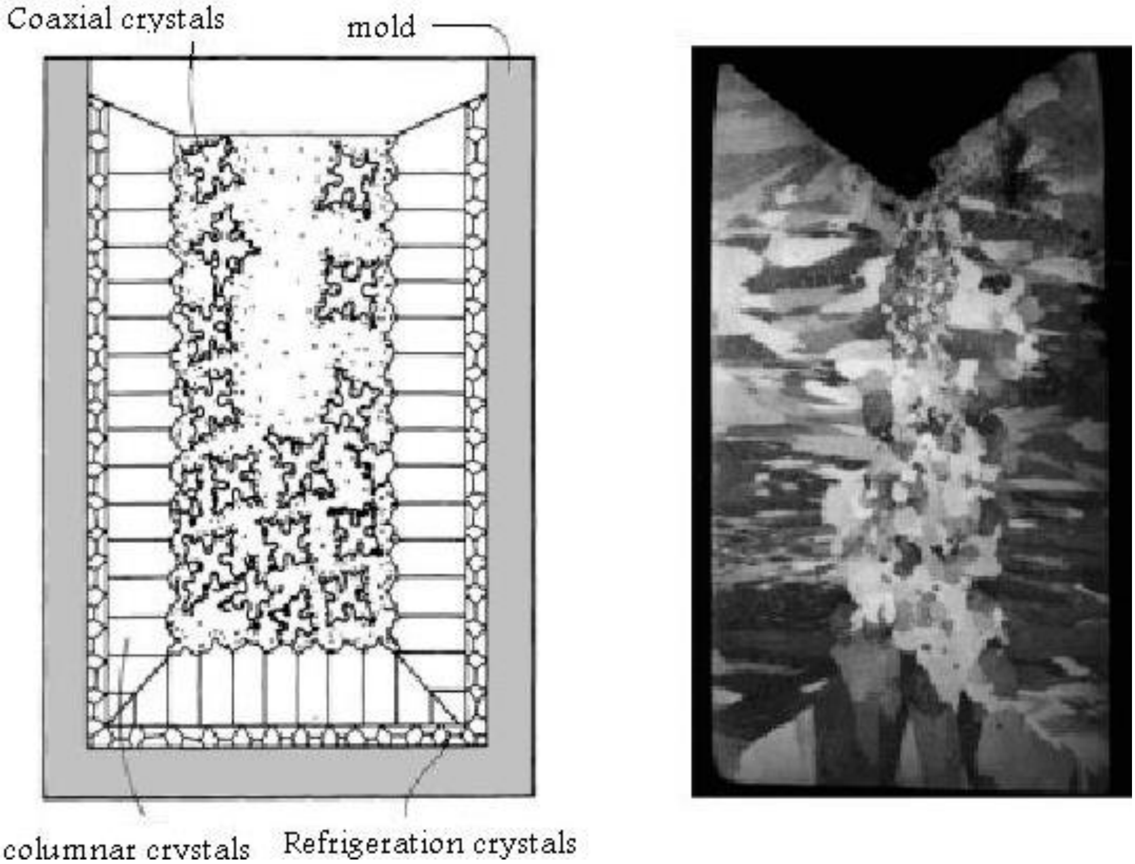


Figure 3: Binary Phase diagram



Coaxial crystals
mold
columnar crystals
Refrigeration crystals

Figure 4

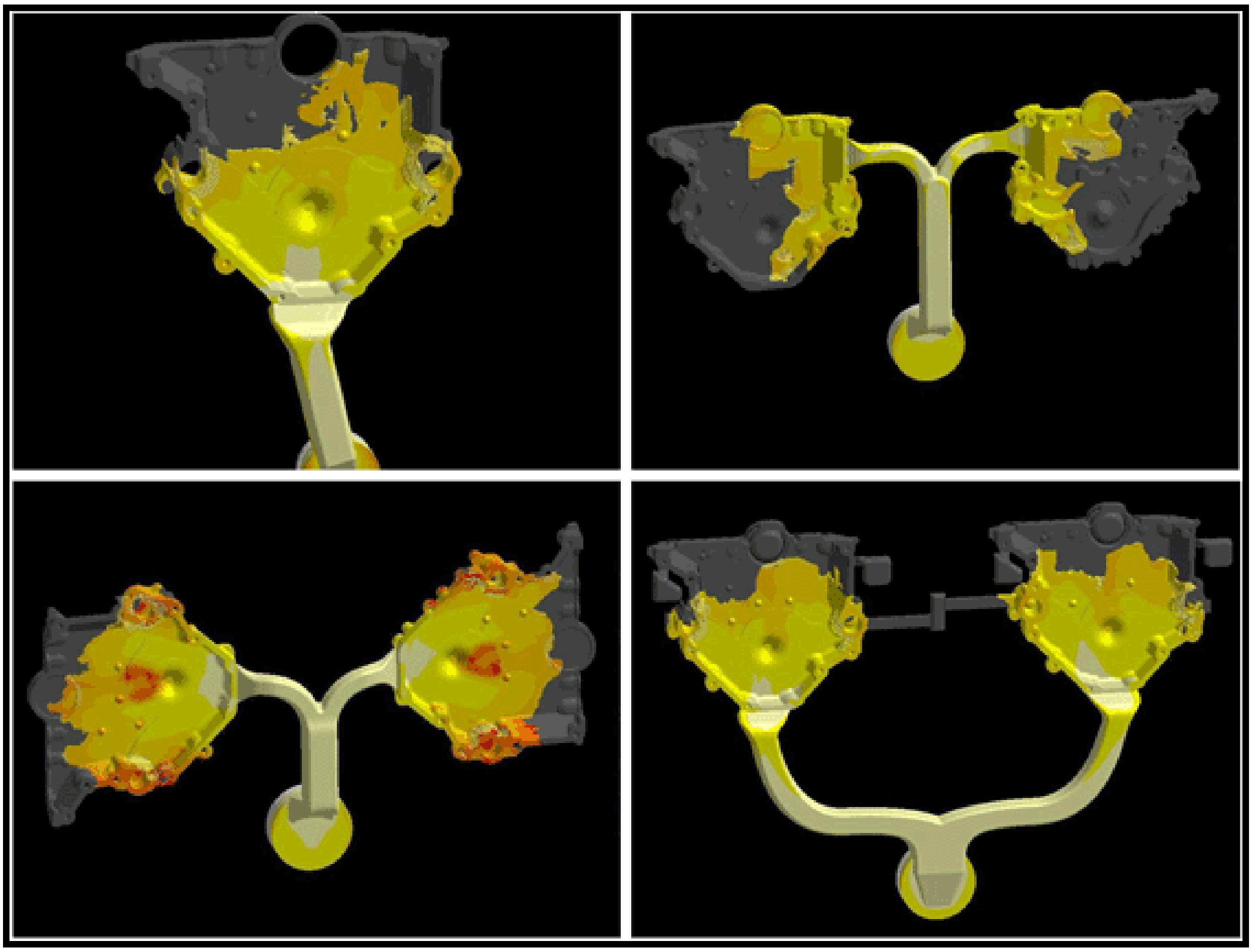


Figure 5: Filling simulation of the real Casting

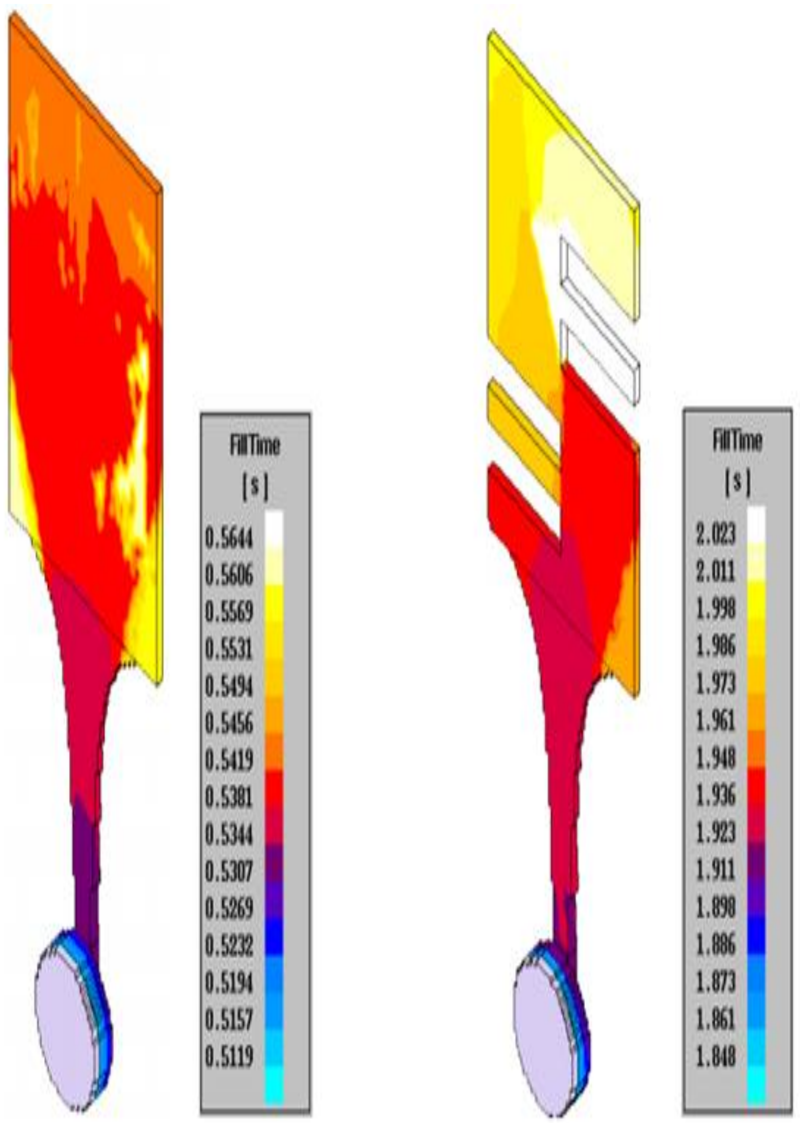


Figure 6. Filling simulation of simple part compared with cutting part

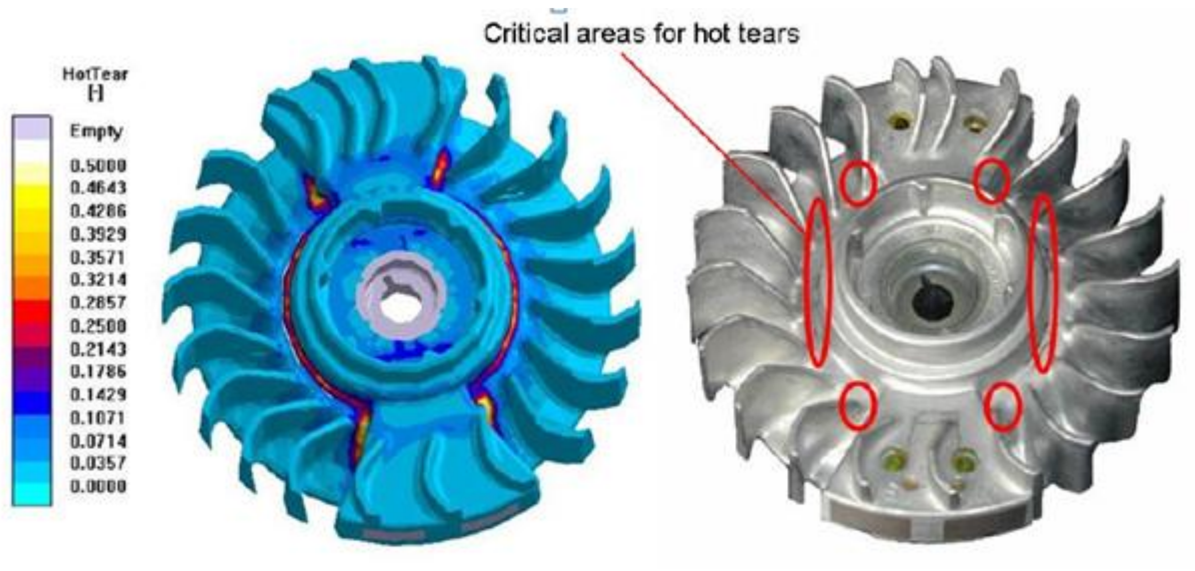
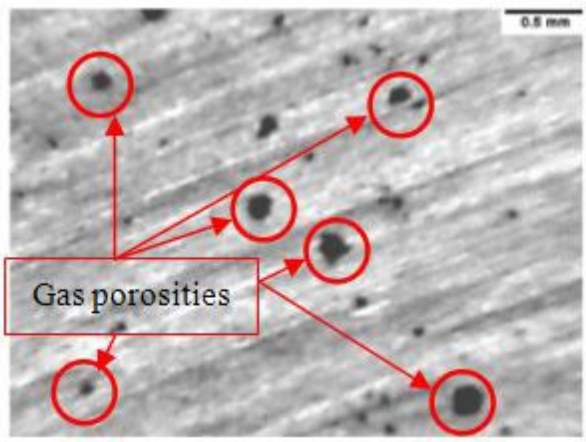


Figure 7: Compared simulation of the real Casting of hot tears

Porosity type of deffects

Porosity type of deffects reduces the quality of the casting usually it's tightness and strenght.

Fig. 8. *Air Porosity in the section of an aluminium diecast part*



The most common porosity type of deffects that appear in aluminium castings processed with high pressure diecasting technology are gas porosity, shrinkage porosity and leaker.

Gas porosity can be described as trapped air in the casting which can come from several sources. It can be caused by poor shot end control, poor venting and overflow function or bad gating and runner design.

In the figure 8 is presented the polished section of a diecast part with gas porosity.

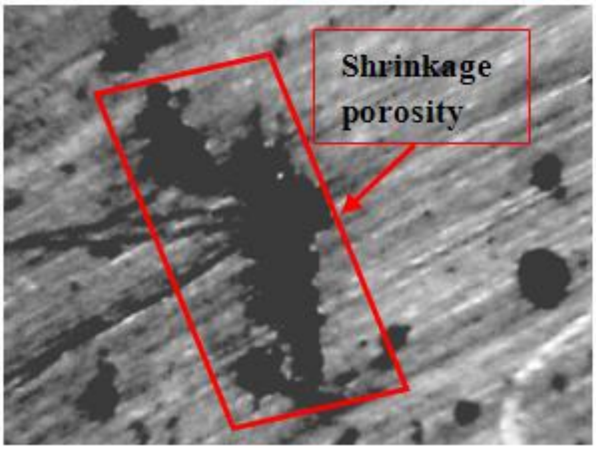
It can be observed the specific shape mostly regular – globular and the opaque shade of the gas porosities.

The shrinkage porosities can be described as internal cracks in the casting which can come from several sources, mainly due to thick walls of the casting. This defect is caused by metal reducing its volume during solidification and an inability to feed shrinkage with more metal before

solidification. Hot spots can also cause shrinkage porosity to be concentrated in a specific zone.

In the figure 9 is presented the polished section of a diecast part with shrinkage porosity.

It can be observed the specific shape mostly iregular – longitudinal and the bright shade of the shrinkage porosities.



In the **figure 9** are analyzed the dimensions of the shrinkage porosities with the microscope.

Main causes for porosity type of deffects in high pressure diecast aluminium parts

Porosity type of deffect can be caused by several factors and process parameters.

The main causes for gas porosities can be grouped in more chategories and are the following:

- Shot end parameters: First stage velocity too low; First stage velocity too high; Change over point too early; Change over point too late; Second stage velocity too low; Intensification too late; Intensification too low;

- Metal volume: Wrong shot weight setting on ladle; Blocked pour hole; Blocked launder on dose furnace; Tube constricted on dose furnace

- Clamping & Ejection: Irregular operating cycle

- Die surface: Not enough plunger lube/sticking plunger; Die is too cold; Too much die spray;

- Vacuum & Venting: Leaking vacuum; Vacuum on too soon/late; Ineffective venting and/or overflows

- Metal: Metal is too hot/cold; Metal is contaminated and/or dirty; Metal is out of specification; Dross in holding furnace

The main causes for leaker are the following:

- Shot end parameters: Metal pressure too low; First stage velocity too low; First stage velocity too high; Change over point too early; Change over point too late; Wrong deceleration

Porosity control methods

Die construction: Poor die/ shot sleeve surface finish; Poor gating and runner design; Poor thermal control/ hot & cold spots; Difficult casting geometry

- Die construction: Poor gating and runner design; Difficult casting geometry

- Metal: Metal is too hot/cold;

The main causes for shrinkage porosities are the following:

- Shot end parameters: Metal pressure too low; Wrong deceleration setting; Second stage velocity too low; Second stage velocity too high; Intensification too late; Intensification too low;

- Metal volume: Wrong shot weight setting on ladle; Blocked pour hole; Blocked launder on dose furnace; Tube constricted on dose furnace

- Clamping & Ejection: Irregular operating cycle

- Die surface: Not enough plunger lube/sticking plunger; Die is too hot; Not enough die spray;

- Die construction: Poor gating and runner design; Poor thermal control/ hot & cold spots; Difficult casting geometry

setting; Second stage velocity too low; Intensification too late; Intensification too low;

- Die surface: Water in cavity/leaking water channel; Leaking oil heating/ cooling unit; Too much plunger lube; Not enough plunger lube/sticking plunger; Die is too cold; Die is too hot; Too much die spray;

- Vacuum & Venting: Leaking vacuum; Vacuum on too soon/late; Ineffective venting and/or overflows.

- Metal: Metal is too hot/cold; Metal is contaminated and/or dirty; Metal is out of specification; Dross in holding furnace

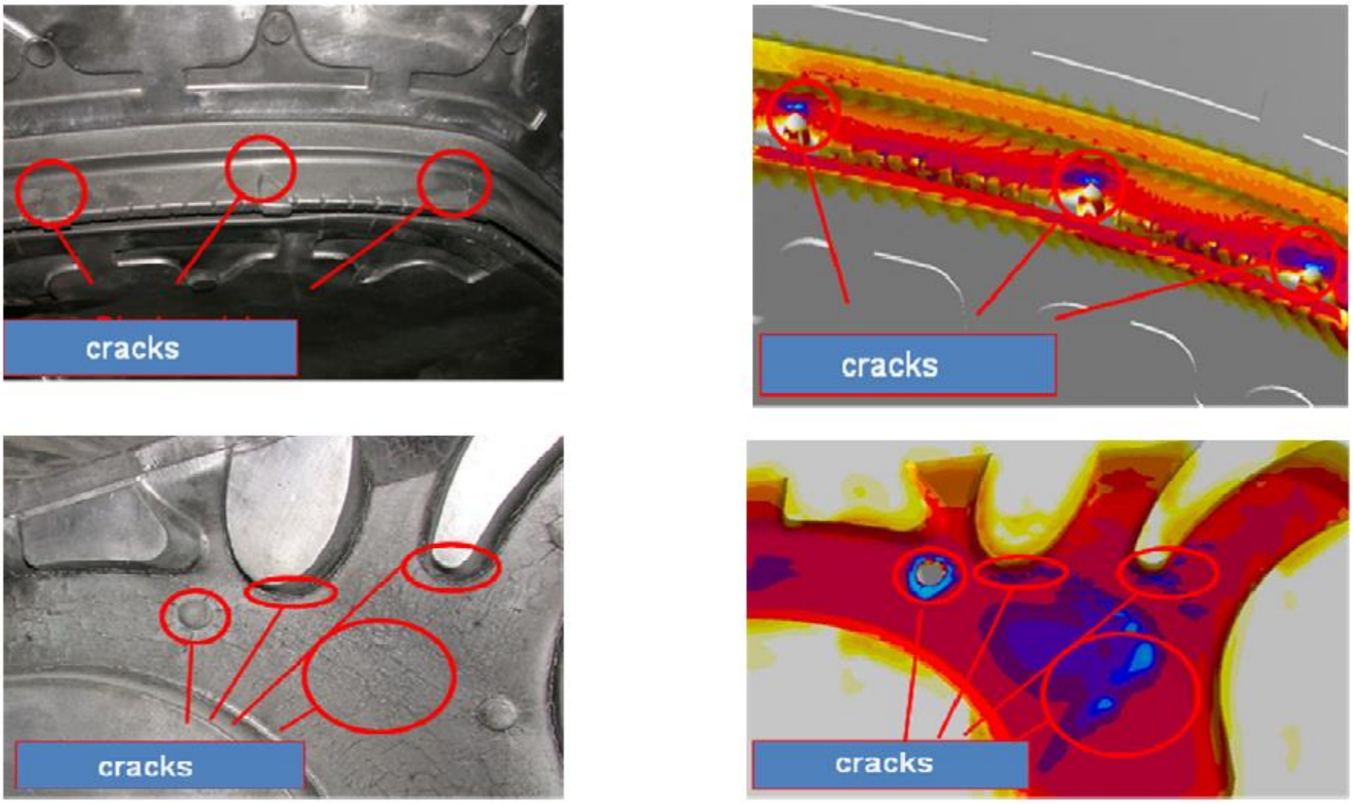


Figure 10: Simulation compared with real casting of cracks

Stresses of Engine blocks

Cast iron engine blocks can be found in more than half of all passenger cars. Their performance and weight are, among other criteria, dependent on their geometry and the casting process, especially defects like porosity and residual stresses.

Only by using manufacturing process simulation, is it possible to determine the distribution of residual stresses in castings and to consider these properties in the design optimization process. Residual stresses develop during solidification and cooling of the casting due to uneven cooling rates in the different wall thicknesses.

Tensile stresses, those stresses that are induced by "pulling", may be critical during the manufacturing process, if their value exceeds the material's tensile strength. By reaching this value, cracking occurs and the part fails. As a rule, tensile residual stresses are lower than this threshold value and the casting does not fail during the casting process.

Nevertheless, even if tensile stresses are below the critical value, the casting may fail during assembly, or even worse during driving.

Compressive stresses are the opposite of tensile stresses and are those stresses that are induced by pushing. It is unusual that compressive stresses are critical. One can try to use compressive stresses as a pre-loading, like in pre-tensioned concrete.

The biggest influences on residual stresses in castings are the design (80%) and the casting process itself (20%). To avoid problems, a manufacturing process simulation can be performed at an early stage of the design process, where geometric or casting process modifications may be made to decrease the level of tensile stresses. This approach leads to an optimized design and casting process of the engine block.

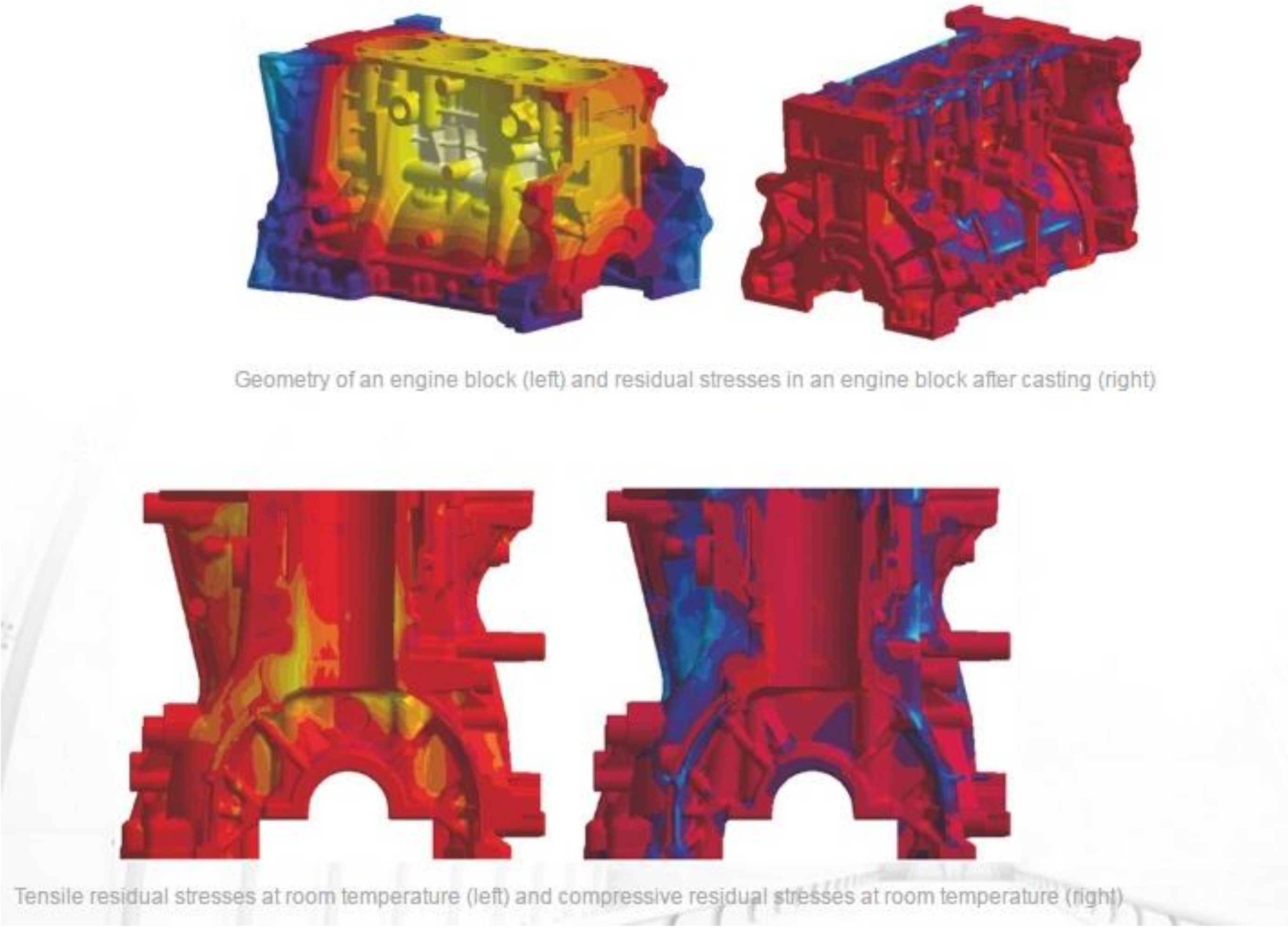


Figure 11 Stress for engine block.

4. Conclusion

Some casting engineers gave up hope. The casting is designed by the design engineer without specific consideration of the manufacturing process. The toolmaker prioritizes on his own process. All problems of the whole manu facturing process are passed on to the foundryman. This applies to designing heavy sections in the casting as well as to not systematically elaborating the position of the ingates, the cooling channels, or the overflows. If the foundryman accepts those conditions without objection, he decreases to a simple metal pourer. Chances arise by the endeavour of great automotive companies to create an integrated development and manufacturing chain. This includes integral cost awareness, i.e., also the designer needs to contribute to a cost effective production. It is understandable that the designer doesn't want to perform the casting simulation by himself,especially as he profit from the cost reductions in the further course of the manufacturing chain. This is the chance for the foundryman to provide prompt and capable input with the use of simulation and also to point out requirements in respect to the production of new designs. This kind of assistance can also be offered by service providers. In theirown interest, foundryman should be involved in and pro-actively work on the processes as early as possible.

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