Cast iron – a predictable material

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Abstract: High strength compacted graphite iron (CGI) or alloyed cast iron components are substituting previously used non-ferrous castings in automotive power train applications. The mechanical engineering industry has recognized the value in substituting forged or welded structures with stiff and light-weight cast iron castings. New products such as wind turbines have opened new markets for an entire suite of highly reliable ductile iron cast components.

During the last 20 years, casting process simulation has developed from predicting hot spots and solidification to an integral assessment tool for foundries for the entire manufacturing route of castings. The support of the feeding related layout of the casting is still one of the most important duties for casting process simulation. Depending on the alloy poured, different feeding behaviors and self-feeding capabilities need to be considered to provide a defect free casting. Therefore, it is not enough to base the prediction of shrinkage defects solely on hot spots derived from temperature fields. To be able to quantitatively predict these defects, solidification simulation had to be combined with density and mass transport calculations, in order to evaluate the impact of the solidification morphology on the feeding behavior as well as to consider alloy dependent feeding ranges.

For cast iron foundries, the use of casting process simulation has become an important instrument to predict the robustness and reliability of their processes, especially since the influence of alloying elements, melting practice and metallurgy need to be considered to quantify the special shrinkage and solidification behavior of cast iron. This allows the prediction of local structures, phases and ultimately the local mechanical properties of cast irons, to asses casting quality in the foundry but also to make use of this quantitative information during design of the casting.

Casting quality issues related to thermally driven stresses in castings are also gaining increasing attention. State-of-the-art tools allow the prediction of residual stresses and iron casting distortion quantitatively. Cracks in castings can be assessed, as well as the reduction of casting stresses during heat treatment.

As the property requirements for cast iron as a material in design strongly increase, new alloys and materials such as ADI might become more attractive, where latest software developments allow the modeling of the required heat treatment. Phases can be predicted and parametric studies can be performed to optimize the alloy dependent heat treatment conditions during austenitization, quenching and ausferritization.

All this quantitative information about the material's performance is most valuable if it can be used during casting design. The transfer of local properties into the designer's world, to predict fatigue and durability as a function of the entire manufacturing route, will increase the trust in this old but highly innovative material and will open new opportunities for cast iron in the future.

The paper will give an overview on current capabilities to quantitatively predict cast iron specific defects and casting performance and will highlight latest developments in modeling the manufacture of cast iron and ADI as well as the prediction of iron casting stresses.

Key words: casting process simulation; cast iron; defects; casting performance; development

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1 Introduction

The metal casting industry has always tried to balance both technical and commercial needs, maintaining engineering capabilities, ensuring efficient operations and protecting business profitability. Commerce at its root has not changed. What is changing is the way that commerce is carried out. There is a tremendous decentralization underway. Casting clients are outsourcing responsibilities and globalizing more and more. As such, the technical requirements and breadth of responsibility placed on metal casters have become even more demanding. This places additional requirements on our engineering resources and challenges us to think about new ways to shorten lead times, reduce total costs, and technically interact with clients more effectively.

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The pace of change in today's marketplace is so rapid that time-to-market has to be the overriding priority. All too often metal casters feel forced to compromise on innovative ideas or approaches because it is believed there simply isn't enough time. With rapidly evolving CAE technologies including comprehensive casting process simulation, automatic casting process optimization, and new computer based component design tools it is possible for metal casters and designers to work together, concurrently, to optimize component design and casting process parameters. Through these engineering efforts metal casters can assure the sustainability and growth of their businesses while maintaining a sizable technical edge over competition [1-5].

Optimized component designs and casting processes using new engineering tools are achieved in concert with strong interactions from casting engineers and designers. This integration and human collaboration is critical for the successful speed-up of the design-process chain. Designers need strong support by casting experts to be able to take full advantage of casting performance, concerning its design and properties. Quantitative results about casting performance provided by casting process simulation help designers to understand the impact of the process on the performance of castings in use.

The steadily increasing computer performance is another driving force for the application of CAE tools in casting development. As we look into the near future, the potential of computational process optimization is shown. Instead of time consuming trial and error on the shop floor, foundry men will use computer tools for an automatic optimization of casting lay-outs or process conditions [6].

Substitution of processes and materials in automotive and mechanical engineering industries has become a standard routine during design of new components. This is a growing challenge for the classical construction material cast iron. Foundries have responded to this threat to their original markets using alloys with improved material performance and with new processes allowing them to cast reliable parts, which were not thinkable 10 years ago.

Making cast iron, ductile iron, compacted graphite iron or even austempered ductile iron to meet today's specifications requires a profound understanding of the material and the process robustness. Here, casting process simulation has been extremely instrumental. During the recent decade the technology of simulating the casting process and predicting the resulting material properties has been helpful in two ways: Firstly, making the mold as a black box transparent for the foundry specialist helps him to understand the causes of possible problems prior to the first casting. Secondly, developing virtual simulation tools for the casting process requires a profound and quantitative understanding of the impacts of physics, metallurgy and chemistry as such. This has changed the empirically driven process substantially into a first principle based and reliable manufacturing process.

For many cast iron foundries, casting process simulation has become a daily standard tool to assess gating and risering and predict feeding. It has become an instrument in quality systems and process optimization. State-of-the-art simulation tools consider the special material behavior of cast irons with respect to its alloy composition, melting practice and metallurgy.

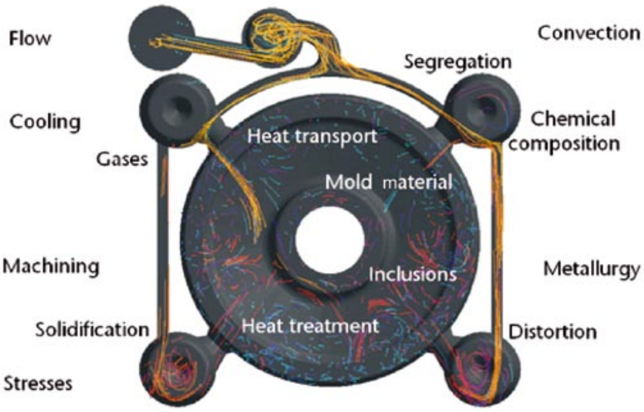

Fig. 1: A challenging task: simulating the casting process to predict component properties. *The biggest benefit of the casting process is its ability to perform many tasks at the same time. However, it is also its biggest drawback, as many process parameters are linked to each other and have to be considered simultaneously.*

The current development efforts go far beyond the evaluation of casting and solidification. One focus is related to the prediction of complex defects resulting from an interaction of metallurgy and process. A second development aspect is focused on the modeling and prediction of the entire manufacturing route. All that is required to get to the ultimate goal of casting process simulation: the prediction of local casting properties to assess the component's design, the entire technology and its economic impact on the profitability of cast iron castings.

2 Pre-conditions for a successful use of casting process simulation for cast iron

The melting and metallurgical practice applied have a decisive impact on the casting integrity. This is especially true for cast iron components, in which the metallurgical processing is decisive for the ultimate casting structures and properties. Only if casting process simulation is capable of considering the impact of alloying and metallurgy, can casting structures be predicted locally.

The support of the feeding related layout of the casting is still one of the most important duties for casting process simulation. Depending on the alloy poured, different feeding behaviors and self-feeding capabilities need to be considered to provide a defect free casting. Therefore, it is not enough to base the prediction of shrinkage defects solely on hot spots derived from temperature fields but also to be able to quantitatively predict them. Solidification simulation had to be combined with density and mass transport calculations in order to evaluate the impact of the solidification morphology on the feeding behavior, as well as to consider alloy dependent feeding ranges. This is accomplished through the description of temperature dependent thermo-physical properties.

The special feeding behavior of cast iron and the strong dependency of its solidification behavior on the metallurgy mean that a macroscopic hot spot prediction is not sufficient to assess the methoding of iron castings. In ductile iron, big hot spots mostly result in a perfect precipitation of the graphite and hence in a sound casting. On the other hand, small hot spots occurring early during solidification may lead to strong shrinkage due to austenite contraction and suppression of graphite.

To be able to predict the soundness of cast iron based on the real local shrinkage and expansion of the casting the program has to be capable of considering the kinetics of the phases being formed during the entire solidification path individually. For cast iron this means taking into account the effects of all alloying components and additionally the inoculation and melting practice and metallurgy applied.

Every foundry specialist makes use of inoculation and alloy composition to avoid chill effects or eutectic cementite. These influences are superimposed by the local cooling conditions. A pure simulation of macroscopic heat flow can not take this coupled interaction into account. Therefore, so called microstructure models, which predict the amount of new phases based on the above described interactions for any location within the casting at any time, are applied.

The different capabilities of both models are best evaluated using "simulated" cooling curves. Whereas in macroscopic thermal models the material (thermo-physical) properties are fixed for the used alloy, in a micromodel these properties are determined at each time step and for every point as a function of the current phase formation. This influences the release of latent heat and finally the shape of local cooling curves, Fig. 2. Supercooling, recalescense and growth temperatures are dependent on local metallurgical and thermal conditions as a result of the simulations. In the same way that a real cooling curve is used as a measure for the melt quality, the simulated cooling curve is a proof for the quality of the models used. Knowing the actual state of precipitating phases of graphite, austenite and cementite at any point, feeding and shrinkage can be predicted locally.

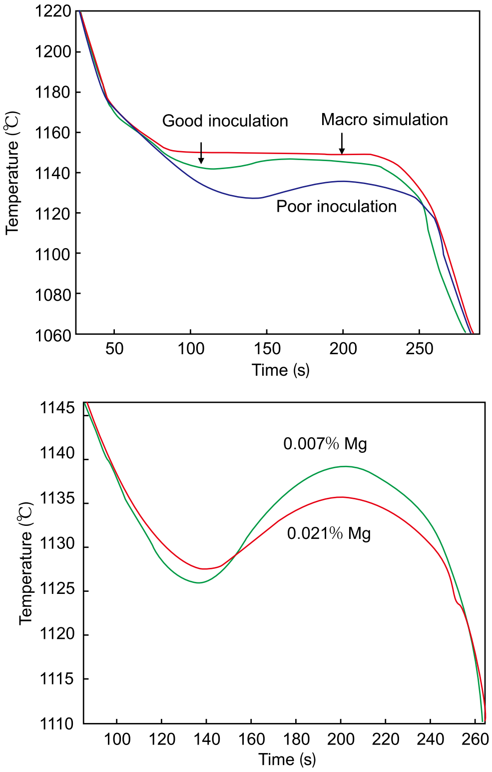

Fig. 3: Sensitivity of cast iron micromodels to the metal treatment applied. *The figures show the differences between macroscopic and microscopic simulation (micromodeling) using simulated cooling curves. While the use of macroscopic heat transfer equations only modifies the shape of the cooling curve due to the released latent heat, micromodeling also considers the impact of different inoculation conditions (top). Even composition changes (i.e. change of effective Mg-content between 0.007% and 0.021%) modify the calculated undercooling, recalescense, and growth temperature (bottom).*

3 Simulation supports methoding and robust process lay-out

The evaluation of a robust and efficient manufacturing route is still one of the main objectives to use casting process simulation in a foundry. Due to the tight interaction of metallurgy and material properties, the foundry specialist still has open questions with respect to filling and solidification of iron castings. This is the case for a reproducible generation of the expected graphite morphology as well as for the feeding performance, which is strongly related to the local graphite precipitation.

A first evaluation of how to make the casting can be done immediately after getting a casting design. Within minutes, the local thermal modulus, which is a good indicator for the casting lay-out, can be determined. Based on these findings, the software can propose locations and riser sizes taken from a database, Fig. 4.

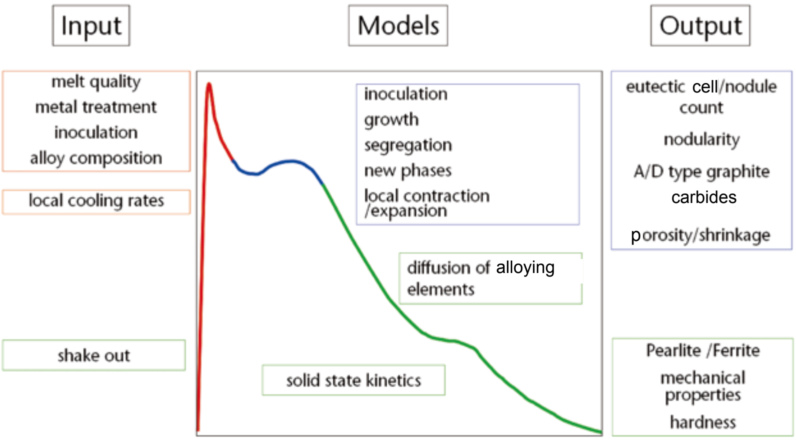

Fig. 2: Modeling of the casting process for cast iron based on micromodels. *Input information, applied models and results available if a microstructure model is applied for cast iron solidification simulation.*

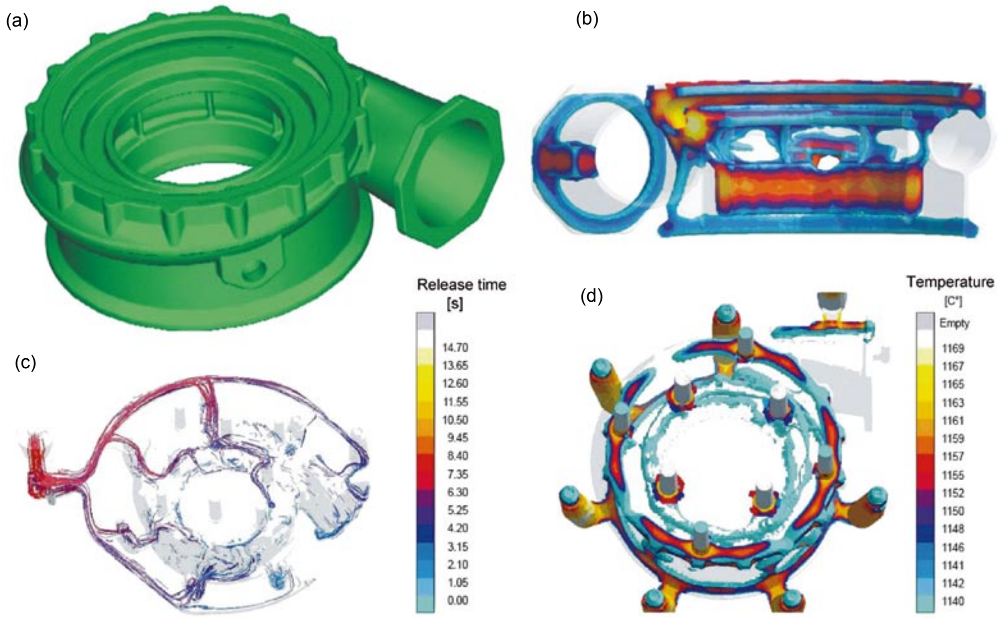

Fig. 4: Set-up of methoding for ductile iron compressor housing. *Based on the raw part CAD-model (a) a quick assessment of local thermal modulus was done (b) to determine the gating and risering lay-out (positions of chills and feeders). Subsequently the entire lay-out is simulated. Mold filling (c) and solidification (d) can be predicted quantitatively* [7].

After designing the gating system and the pattern lay-out a first complete simulation of the entire process can be done. The basis for the simulation is the calculation of different phases and their amounts for the entire solidification of the casting. This allows the determination of the local sum of shrinkage as a function of the currently present contracting (liquid, austenite and cementite) and expanding (graphite) phases and its compensation through feeding from a riser.

Once isolated regions are formed which can no more be fed, the total feeding is a sum of remaining liquid and austenitic shrinkage and local graphite expansion. Additionally, mold stability and mold dilatation must be considered to take the self-feeding effects into account. Only this micromodeling approach enables the prediction of porosity in cast iron, Figs. 5, 6 and 7.

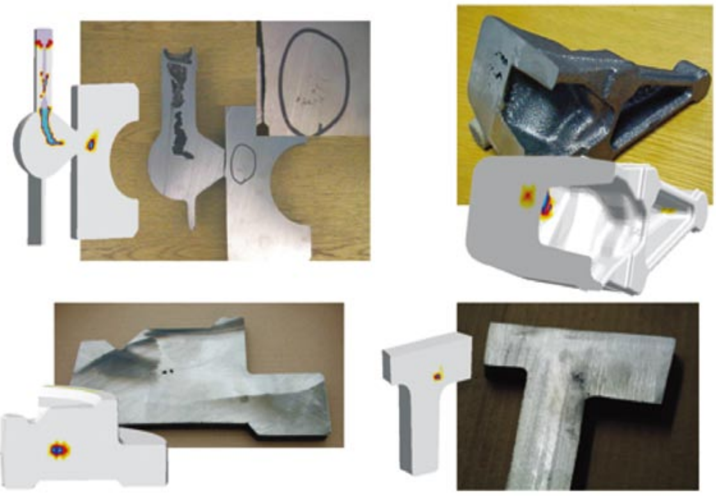

Fig. 6: Shrinkage prediction and reality. *Examples display the accuracy of shrinkage prediction for different cast iron castings.*

Fig. 5: Predicting shrinkage in cast iron components. *Secondary shrinkage below risers is shown for a ductile iron ring casting. This confirms that a simple heat flow calculation is not sufficient, as it only shows a ring shaped temperature distribution in the center of the casting. Only the combination of local shrinking and expansion behavior leads to a correct defect prediction.*

Fig. 7: Is a riser needed or not? *The porosity prediction for an original riserless lay-out for a grey iron grade 250 casting shows problems near the top surface (left picture). The simulation clearly demonstrates the liquid shrinkage to be the root cause of the problem. Porosity prediction for a modified layout shows that a small riser completely compensates liquid shrinkage (right picture).*
*(*The picture is with friendly courtesy of ITT Water and Wastewater AB)*

4 Simulation predicts microstructures and mechanical properties in cast iron

The simulation of individual phases as a function of metallurgy, melting and inoculation practice also allows a prediction of microstructures after solidification (nodule count/ number of eutectic cells, amount of grey/white solidification, amount of austenite/eutectic graphite), Fig. 8. Through calculation of the further cooling and the local segregation down to the solid state reaction, the local phase distribution of the matrix (ferrite/pearlite distribution, coarseness of pearlite) can be assessed quantitatively. This is important information for the quality systems of foundries, Fig. 9.

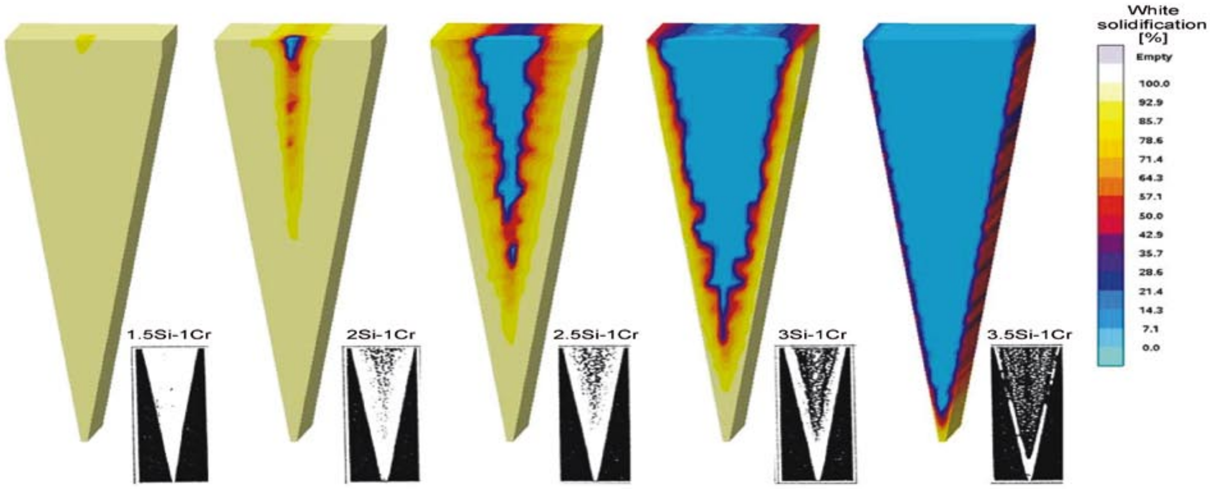

Fig. 8: Simulating the influence of alloying elements on the microstructure. *The transition of grey to white solidification in wedge test samples as a function of alloying elements in comparison to the real microstructure. With increasing Si content the columnar white is decreased and cementite precipitation turns into graphite formation.*

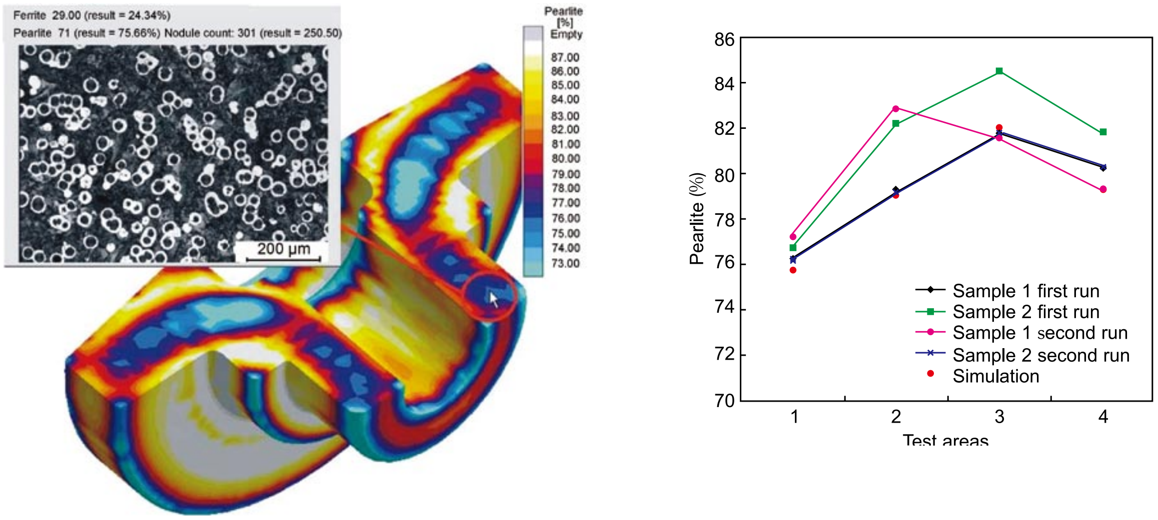

Fig. 9: Assessment of microstructures and mechanical properties for ductile iron. *Due to the consideration of nucleation, phase distribution, segregation of alloying elements and local cooling during solid state reactions, the ferrite/pearlite distribution can be predicted quantitatively. This allows the introduction of simulation into the quality system of a foundry, here shown using the example of a ductile iron hub (left). The accuracy of the simulation results (shown here by comparing the experimental findings and simulation results) helps to reduce continuous testing within the foundry at a customer site (right).*

Micromodeling also allows predicting the transition of different graphite morphologies (e.g. A and D-type graphite and transition from ductile to compacted graphite morphology) as a function of the applied metallurgy, the alloy composition and the local cooling conditions. Figure 10 shows the predicted nodularity distribution in an engine block.

The quantitative knowledge about local phases and microstructure allows the prediction of mechanical properties for the entire casting (tensile strength, hardness, yield strength, elongation and Young's modulus), Fig. 11.

5 Impact of residual stresses on cast iron casting quality

In the past the impact of thermal stresses on the casting quality and performance was often underestimated. Foundries had to deal with casting distortion and cracks, but the measures to avoid problems related to stress formation were limited. Often only additional efforts such as stress relieving treatment could help to meet the specifications.

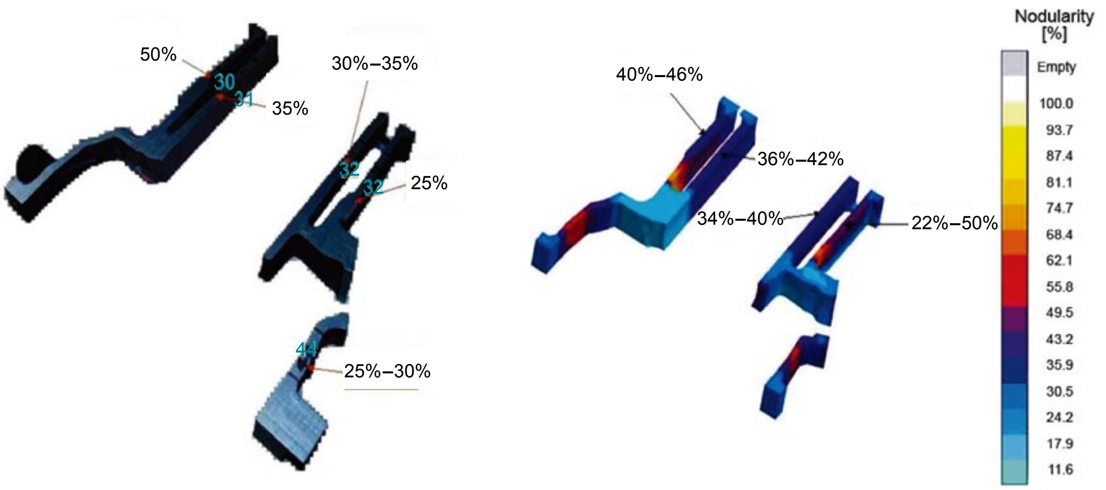

Fig. 10: Simulating local nodularity as a function of alloy, metallurgy and cooling conditions. *Simulated nodularity values are compared with measured nodularity found in an engine block test casting* [4,8].

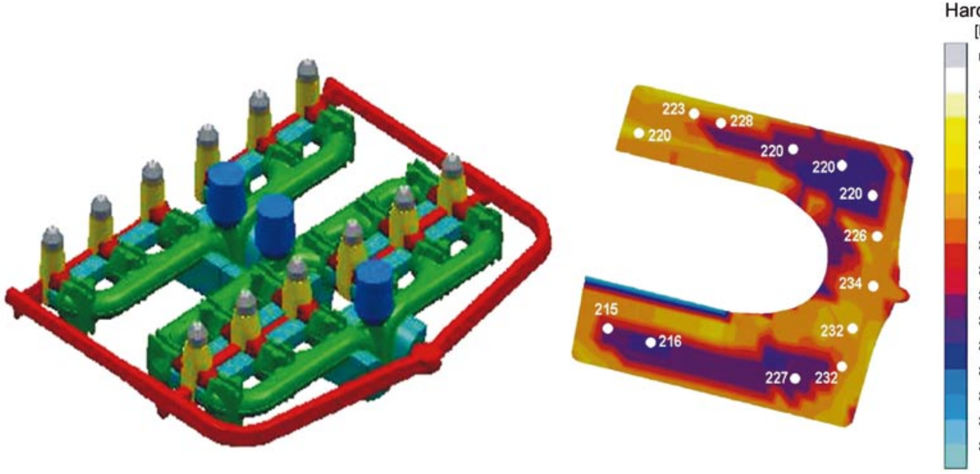

Fig. 11: Comparison of simulated and measured hardness values. *The experimental findings for an exhaust manifold in Si-Mo alloy match the simulated hardness predictions well* [7].

Today, modeling of thermally induced residual stresses has become state-of-the-art. It allows addressing various quality issues, such as hot tearing, crack susceptibility, residual stress levels and casting distortion, Figs. 12 and 13. Opposite to the "continuously" developing processes such as filling, solidification and cooling, stress formation is much harder to understand as the casting always undergoes a stress inversion during cooling. This often leads to misconceptions in daily practice: Why do I measure compressive stresses in the section where I find cracks? This is due to the fact that cracks often initiate at elevated temperatures when the section is in a tensile stress state and the casting structure is brittle. Therefore, it can only resist small strains. At ambient temperatures, the stress in these sections has reverted into a compressive state while the crack is obviously still present. For this reason, evaluating results from casting stress simulations is also a very educative task and helps to understand the causes of quality issues, Fig. 14.

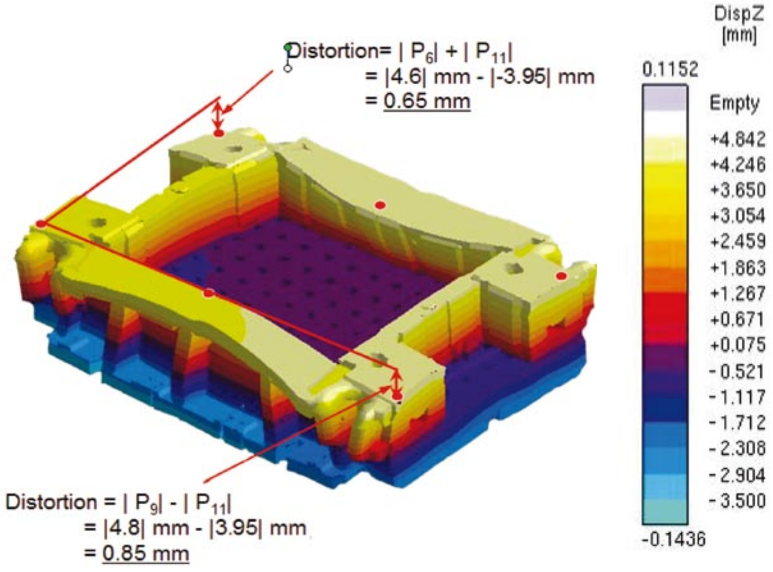

Fig. 12: Residual stresses in cast iron parts shown using the distortion of a stamping press tool. *The simulation of residual stresses down to ambient temperature allows the prediction of local distortion. Surface flatness and linear shrinkage of the casting can be predicted as well as the influence of the stiffness of cores and the mold on the final distortion.*

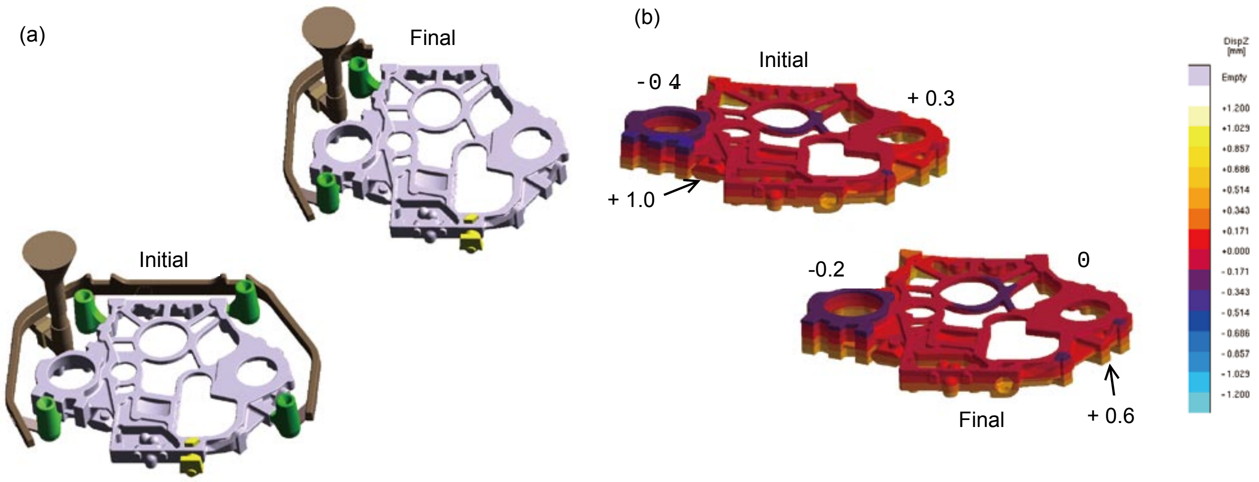

Fig. 13: Optimization of a gating system design leads to reduction of casting distortion. *A grey iron housing experienced problems with casting distortion. As the root course a rigid gating system was identified, which lead to scrap and inoperability during machining due to insufficient machining allowances. A modified gating system was simulated, resulting in a distortion, which meets the specifications and is still maintaining its main objective to guarantee a robust filling and solidification. Figure 13 (a) shows the original gating system (left) compared to the final design (right) pictures Fig. 13 (b) compares the distortion of the initial and the final versions. (*The picture is with friendly courtesy of MWM International, Brasil)*

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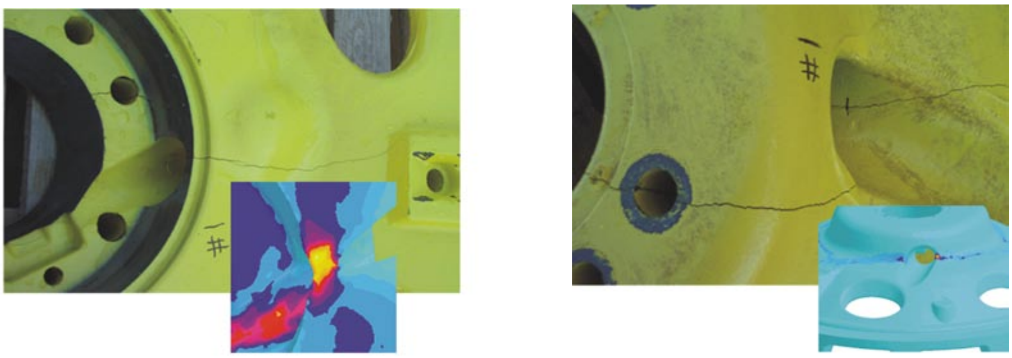

Fig. 14: Crack formation in wheel weights. *These grey iron castings didn't appear to have any defects after casting and did not show any obvious cracks or discontinuities during machining and painting. However, when the weights were mounted to the wheels, cracks appeared. Simulation of residual stresses showed that the material around the valve stem hole was damaged in the casting process. The residual stresses were not high enough to crack the casting during cooling, but the added load during mounting led to stresses exceeding the strength of the cast iron. The simulation depicts the starting point of crack (left). Additionally, high strains and strain rates during solidification, indicators for hot tearing, led to damaging conditions in the area where the crack migrated through the casting (right). The conclusion was that the design of the casting needed to be modified. With the new design, none of the castings failed during mounting.*

As explained previously, residual stresses can mean a lot for the performance of a casting. Most of castings are machined to be used in assemblies. Any machining operation results in a new stress state of the cast component. Under unfavorable conditions, the machining operation may lead to elevated stress concentrations resulting in casting cracks and failure, Fig.15.

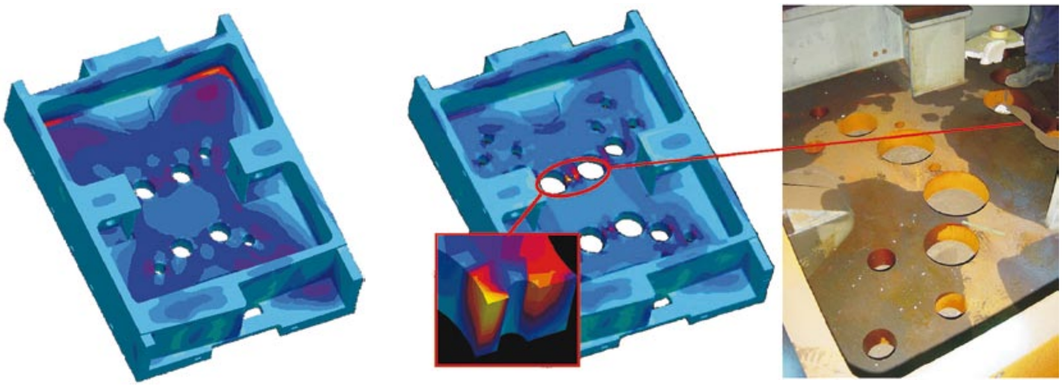

Fig. 15: Prediction of crack sensitive area prior to and after machining. *Simulating casting stresses can also consider the stress redistribution due to removal of gating systems or due to machining. The stress redistribution can lead to high stress concentrations, which may result in the total failure of the cast part. The simulated as-cast residual stresses do not show any significant levels (left), while stress redistribution after machining and cracked casting do (right)* [9].

To avoid high stresses in many cases a dedicated heat treatment is performed to reduce the stress levels in a casting. This expensive process step can be optimized if you know the optimal process conditions and their impact on the casting stress state, Fig. 16.

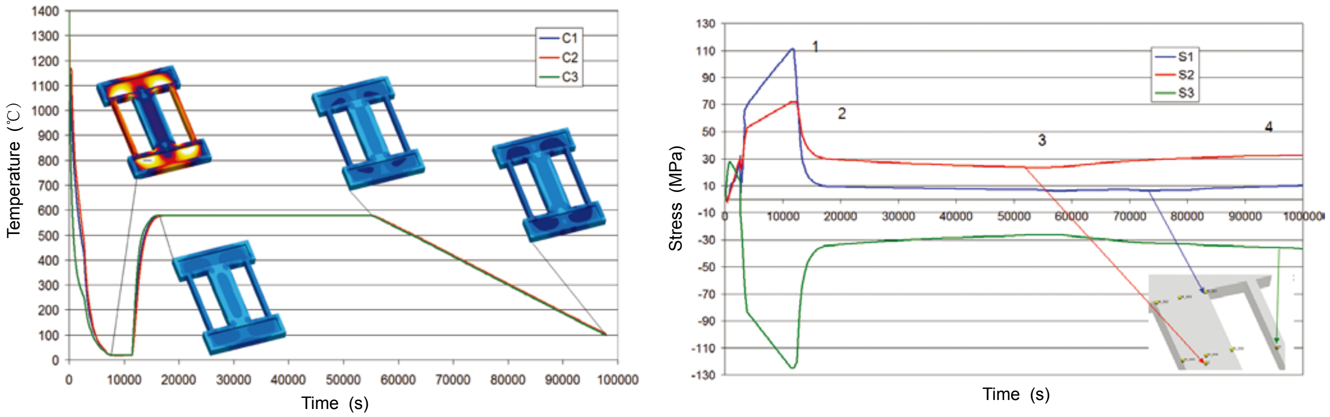

Fig. 16: Stress relief of cast iron components during heat treatment. *State-of-the-art simulation tools allow simulation of the entire manufacturing route of a casting including the heat treatment. The figures show the temperature history from the casting to the end of the heat treatment including the stress distribution in a stress lattice casting (left) and the related stress history at different points (right). As-cast casting stresses may be close to the yield stress of the material (1). Therefore, especially for mechanical engineering castings, a stress relief heat treatment is applied. Annealing leads to a reduction of stresses over time, see (2) and (3). The stress reduction is driven by creep, a complex time dependent mechanism which is a function of temperatures and local stress levels. In any case, a heat treatment can never completely remove stresses. Stresses will never go lower than a certain threshold value, which is dependent on the annealing temperature and time. Due to the cooling at the end of heat treatment, an elastic stress build-up can be recognized (4).*

6 Simulation supports the entire manufacturing route

Aiming for a quantitative prediction of final properties of the cast component when the part is shipped to the customer, casting process simulation must be able to address the entire manufacturing route of castings. In many cases final component properties are determined by subsequent manufacturing steps such as heat treatment.

The industrial application of austempered ductile iron, ADI, has grown in recent years. The material has a number of mechanical properties that makes it attractive for structural applications in industries such as automotive, heavy trucks and many others. The material can be tailored to have properties such as high strength, high wear resistance, high fracture toughness and high fatigue strength.

ADI is an alloyed ductile iron which has been subjected to a three-step process known as austempering heat treatment. The ductile iron is initially heated to an austenitization temperature for a sufficient time to get a fully austenitic matrix saturated with carbon, which will later transform into ausferrite. The level of carbon content is dependent on the temperature, alloying content, nodule count and reaction time.

The second step consists of quenching the ductile iron to the austempering temperature. Here, alloying and cooling conditions are crucial to avoid early ferrite and pearlite phase formation as well as martensitic phase formation. During the third step, the casting is held at the austempering temperature for a period of time, before cooling to room temperature. During austempering, the fully austenitic matrix transforms into acicular ferrite and stabilized high carbon austenite, a matrix called ausferrite. This is known as the first stage reaction, where austenite decomposes into ferrite and high carbon austenite.

The austempering time must thus be long enough so that stable high carbon austenite is achieved and the formation of martensite is avoided. However, if the austempering time is too long, the high carbon content austenite becomes saturated with carbon. Saturated austenite may further decompose into ferrite and brittle carbides. This is known as the second stage reaction, which also must be avoided. The best combination of mechanical properties in ADI is obtained after the first stage reaction has completed but before the second stage reaction begins.

The complex interaction of manufacturing conditions and microstructures is ideally suited to be assessed by process simulation. Knowing the local as-cast microstructure (nodule count, phase distribution and segregation profiles) a coupled diffusion and kinetic model allows the simulation of the local formation of austenite and subsequent carbon pick-up as a function of time and heat treatment conditions, Figs. 17, 18, 19.

Saturated carbon concentration, alloying elements and local cooling conditions are used to determine (undesired) local phase formation during quenching. These phases are the input conditions for a final isothermal micromodel, which considers local diffusion and solid state phase formation as a function of phase kinetics and diffusion. In the model, the formation and growth of ferrite from the austenitic matrix and the stabilization of austenite are predicted. Important information about the end of stage 1 (time of full transition into ferrite) is given by the simulation program to avoid subsequent carbide formation, Fig. 20.

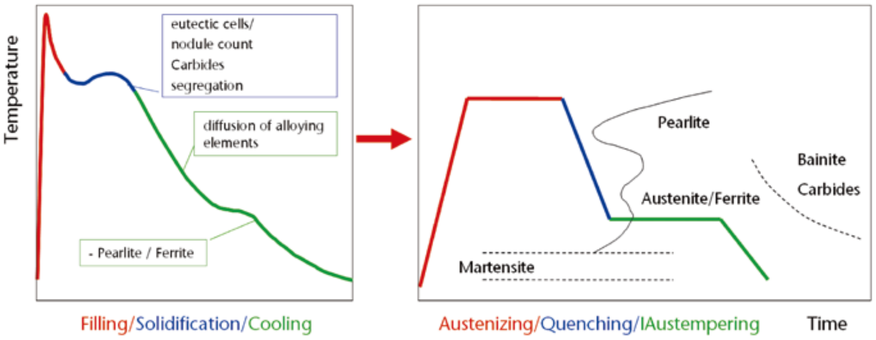

Fig. 17: Integration of casting process simulation and heat treatment simulation to predict ADI structures. *The micromodeling of cast iron provides valuable information about structures and segregation profiles for a subsequent heat treatment simulation. Nodule count and segregation profiles will be used as input values for the simulation of austenitization, subsequent quenching and austempering stages. The simulation provides quantitative information about microstructures at any stage of the heat treatment and allows determination of the required times to reach the respective structure.*

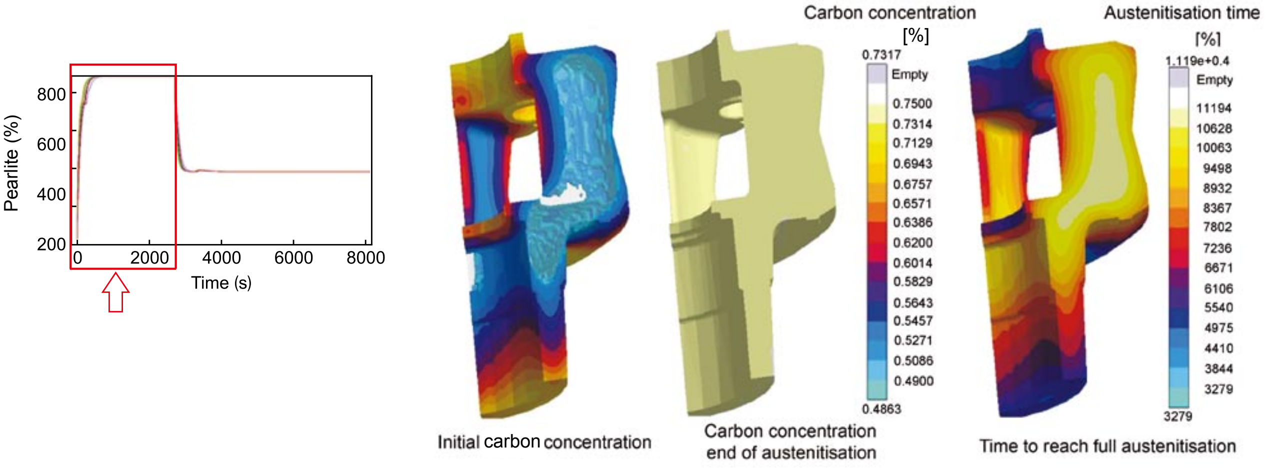

Fig. 18: Simulation of austenitization of a planet carrier. *Based on the local as-cast structure the phase change from solid state phases into austenite and the subsequent carbon saturation can be modeled. As a result, the carbon levels and the time to reach the full saturation will be predicted.*

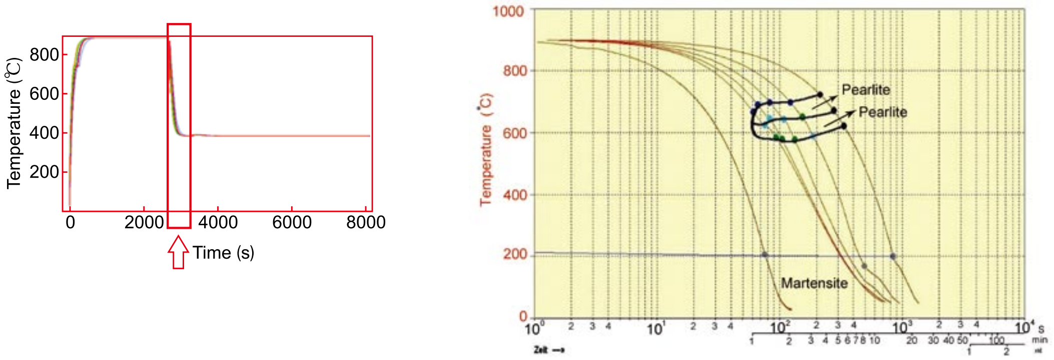

Fig. 19: Simulation of quenching. *The most important goal during quenching is to keep the saturated austenite and avoid ferrite and pearlite formation. This is strongly dependent on the composition of the alloy (in particular due to Ni and Mo additions). Especially for heavy sectioned castings the local cooling rates can be modeled. As they can be quite different, simulation helps to determine critical process conditions.*

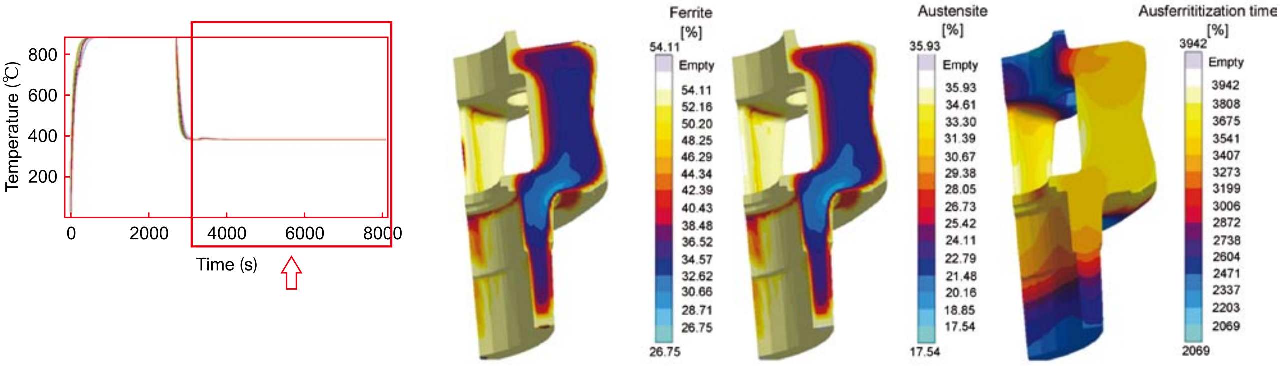

Fig. 20: Simulation of ausferritization. *A further model includes nucleation and growth of ferrite and diffusion of carbon into the austenite. This leads to a quantitative prediction of final phase distribution and the time to reach the full ausferritization.*

7 Simulation supports casting design for performance

The quantitative knowledge about local properties helps both the foundry specialist and the casting designer. The foundry man can set up a robust process guaranteeing the required specifications. The designer can make use of local properties for his design considerations to fully exploit the potential of the casting. This has strongly supported the development of new and innovative cast components, such as wind turbine castings, Fig. 21.

Fig. 21: Casting process simulation strongly supports the development of wind power casting technology. *Compared to welded parts, castings offer much better fatigue properties, which is essential for components with a required minimum lifetime of 20 years. The weight of the castings is a critical factor for the functionality and price of a wind turbine. This means designer and foundry must strongly cooperate to take full advantage of the material performance for an optimized part. (*The picture is with friendly permission of Vestas, Norway)*

Even for the introduction of “new” materials, casting process simulation using micromodeling is used. The lay-out of a new generation of engine blocks using compacted graphite iron was massively supported by new developments in structure prediction tools, considering the metal treatment to predict local nodularity and shrinkage susceptibility (Fig. 10) [4].

An optimal use of cast iron properties is only possible if the potential of the material is used by the designer to its full extent. This regards both weight savings as well as design for optimal performance in use. For this purpose, casting designers are asking for clear design rules and tools to support the design of the component.

Besides the geometry, iron casting properties are dependent on defects, the graphite morphology and the structure of the matrix. The metallurgy chosen and the process control are main influencing parameters for the casting performance. It results in an uncertainty of designers about the real casting properties they can count on. Therefore casting standards are applied to secure the minimum requirements. Until now, designers consider varying casting properties as more of a threat than as an opportunity[10].

This makes clear that an intense coupling of casting process simulation and simulation for performance is needed. The full use of the material potential can only be realized if the real material properties resulting from the casting process are introduced for the load calculations of the designer, Fig. 22. Casting process simulation must answer questions which will be posed by both the foundry specialist and the designer. Therefore, it is important that simulation is able to predict cast iron material behavior not only qualitatively but also quantitatively.

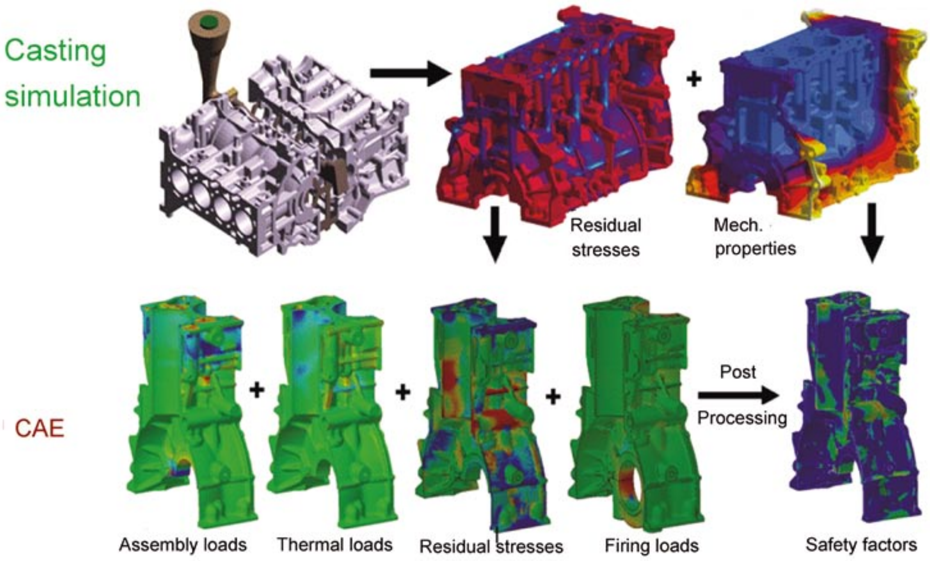

Fig. 22: Integrated CAE design-process chain. *Only a coupled use of casting process simulation and performance simulation allows the assessment of the real material performance in a component with respect to its local mechanical properties and residual stresses*[11].

The integration of structure, defect and property modeling of castings into the CAE world enables the designer to assess the durability of his part based on the real performance of the casting, Fig. 23. Alternatively, the material potential can be used for weight savings.

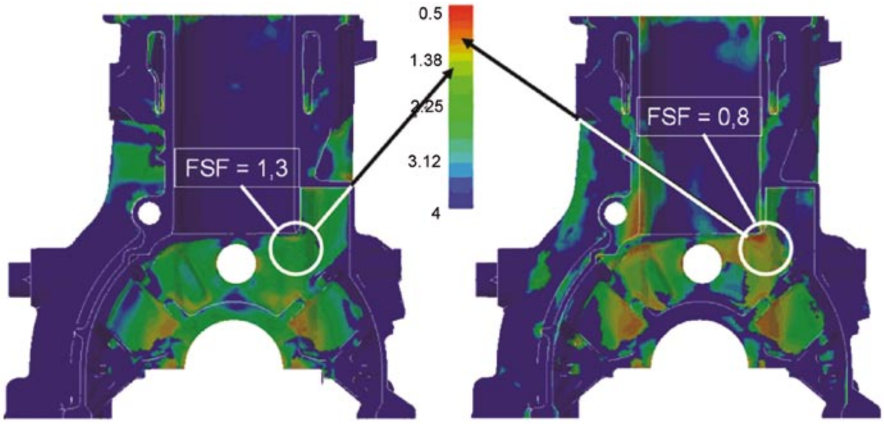

Fig. 23: Impact of as-cast residual stresses on durability of a cast iron engine block. *The classical life time prediction does not consider stresses resulting from manufacturing. The stress free casting shows a safety margin of 130% in a critical area (left). If residual stresses from the casting process are considered as an additional load, the safety margin in the critical area drops down to 80% (right). On the other hand, compressive residual stresses will increase the durability* [12].

8 Summaries

The beauty of the casting process, realizing a complex component "in one pour" becomes a challenge if the complexity of the interactions between the different quality determining parameters are considered. A simulation tool has to meet this challenge, especially with respect to the complexity of cast iron solidification. Only if the degrees of freedom the foundry specialist has to manufacture sound castings are implemented in a simulation program, can the software become a tool for daily process and production optimization in a foundry.

On this background, the main goals of a foundry to use a casting process simulation tool - reproducible quality, increased profitability, adequate design for manufacture and entering into new markets - strengthen the competitiveness of the casting process as such. In this context "casting quality" means more than "soundness", "cost reduction" means more than "improved yield", and "casting properties" mean more than "meeting required standards". The information provided by state-of-the-art casting process simulation tools supports the component's designer in achieving a design which considers the material and process demands as well as supports the foundry specialist in setting up a robust manufacturing route.

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