Modeling and simulation in high pressure die casting

Basics and use

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Innovations and modifications in the techniques of high pressure die casting or tooling are forced by trends in part design, part load as well as by costs and times for development and manufacturing processes. All current trends require continuous improvement in planning of part performance and production processes. The quality of parts and the efficiency of development and manufacturing processes are primarily depending on the quality and accuracy of the planning process.

Generally, there are two crucial factors that secure the reliability of planning:
Experiences from past projects that can be used in future projects, and
Modeling of processes based on general physical laws.

As die castings and casting processes get more and more complex, it becomes increasingly difficult to use experience from past projects in future projects (M. Jolly, 2000). At the same time, due to restructuring processes in the casting industry, less information is documented and stored and thus not available in the future.

In high pressure die casting the term ‘modeling’ means the reproduction of the casting process in simulation programs. In this method, the very detailed process flow is specified as a boundary condition in a calculation. The result is the representation of die filling, solidification, formation of microstructure and properties, as well as development of residual stress and distortion in the castings. The simulation results can be displayed on screen, printed as color graphics, or represented three-dimensionally and thus are excellent records of the anticipated results of the die casting process. As this is the quickest and most cost-effective method to develop a high-value product, die casting modeling gets more and more important.

Model specifications

In the numerical simulation of casting processes, three-dimensional differential equations are used as mathematical-physical models. Mass flow, heat flow, or development of stress are coupled to the casting process and can be modeled by coupling the respective differential equations. For die filling, e.g., there are equation systems, which are able to describe occurring phenomena like turbulent three-phase flow with possible phase transitions. However, simulations that use such detailed model specifications require very long computing times, even on supercomputers. But it is not always necessary to use a very detailed description for the practical use of the simulation. In order to get a basic understanding of the processes during phase transition it is also possible to use other simulation techniques.

Basically, the term ‘modeling’ means the idealized replication of an object or of a process. A good model mirrors the essential characteristics of the original, but at the same time uses valid and clever simplifications. The modeling of a complex, technical operation like the high pressure die casting process means to define, to quantify, and to take into consideration the characteristic values and influential mechanisms of the process (P. N. Hansen et al., 2001, W. Maus et al., 2001).

The simulation of die casting needs to replicate the following typical problems:
Patterns and temperatures in the melt flow: last filled areas, venting of the die, aggregation of die agents, ‘dead areas’ in the runner, turbulences in the melt, disintegration of the melt and merging of melt fronts, cold shuts, or weld lines.
Temperatures of the die: the complete die filling (especially during thin-wall casting), cycle times, core wear, adhesive tendency, or heat loss when spraying.
Solidification of the casting: the creation of shrinkage cavities and pores, hot tears, microstructure formation, possible feeding in the final pressure phase or during local squeezing, as well as the formation of residual stress and consequently arising distortion.

The integration of the simulation results into the decision making processes during casting design or in the foundry assumes that the calculations generally last no longer than one day, counting from the availability of an accurate 3D-CAD-model of a casting including ingates to the creation of the documentation of the calculation. With these factors in mind, there are the following models and examples to review:

**Models for die filling**
In the majority of cases the Navier-Stokes equation is used to describe pressure-driven flow. This equation needs to be solved coupled with the Fourier heat conduction equation in order to consider the heat loss of the melt during die filling. Regarding flow, basic approaches for single phase and laminar flow are used. With specific extensions of the models, further phases like air and solidified melt are considered (M. Lipinski, 1996). The phenomena of turbulences are taken into account by using k/ε approaches (D. B. Spalding, 1983, W. Shyy, 1994, and W. J. Minkowycz, 1988).

**Models for solidification**
The Fourier heat conduction equation is used for these models. Here, phase transformation enthalpies like melt heat need to be considered according to the solidification laws (S. Neves, 2002). Effects like the different precipitation of solidification phases in dependency on supercooling are increasingly in use (S. Andersen et al., 1990, E. Flender, 1993). If the used modeling approaches consider values calculated during heat flow simulation, like local solidification time, cooling rate, or temperature gradient, the formation of microstructures can be computed (E. Flender et al., 1993, Julie Huang, 1998).

**Models for stress calculation**
The formation of residual stresses in castings is very complex, especially in the area of high temperatures. Non-linear, elastoplastic approaches are very sophisticated. It is difficult to describe phenomena like the formation of hot tears as the material laws in combination with high temperatures are not well enough known yet. Further, it is difficult to consider the contact conditions between die and casting, which has a substantial influence on the formation of stresses, especially in high pressure die casting.

**Phases of a simulation project**
In order to run a casting simulation, the following fundamental steps need to be carried out.

**3-D-modeling**
Basis for the simulation is a three-dimensional geometry model of the raw casting or the machined part. The casting developers in the automotive industry focus on maintaining a centrally managed and up-to-date record of geometries that exclusively consists of 3D-CAD data. This way it is nearly impossible that such model doesn’t exist in the automotive industry. In other industries it might happen that a model is not existent and it needs to be developed based on drawings. The geometries of ingates and overflows, as well as of die segments including cooling/heating lines are prepared as 3D-models and need to be available for the simulation, too.

**Enmeshment**
The complete 3D-model, which consists of the raw casting, ingates, overflows and/or vacuum channels, as well as die segments including cooling/heating lines need to be enmeshed for the mathematical calculation. Depending on the operation method, these meshes are exclusively automatically generated (finite volume method), or automatically generated and manually reworked (finite elements method). The completion of the 3D-models and the enmeshment are known as ‘preprocessing’.

**Predefinition of the process parameters**
Before starting the calculations, the required process parameters need to be entered via interactive user interfaces. These process parameters are shot curve, temperatures of melt, thermal regulation medium and die, as well as the chronological sequence of the whole casting process including the
spraying of the die agent. Some simulation programs include subroutines that automatically forecast and propose appropriate process parameters.

**Execution of the calculations**
The actual calculation can be carried out on various hardware platforms. The complete calculations usually run overnight on powerful machines, but with the use of cluster computers and appropriate simulation programs, the calculation can be completed within minutes (W. Schäfer et al., 2000).

**Evaluation of the results**
‘Postprocessors’ prepare the results in colored 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.

The time needed for the run of the simulation is depending on various parameters and can range between 30 minutes (for the determination of the ingate position and the requirements for thermal balancing of the die) and two days (for the calculation of die filling, solidification, and formation of residual stress with more cycles for a complexly structured casting).

**Automated numerical optimization**

With the help of simulations it is possible to ‘x-ray’ the casting process that was elaborated by qualified personnel. The results of the simulations support the decision-making-process in order to implement improvements. Thus, the use of casting simulations is always dependent on the employment of qualified personnel. The labor costs in a simulation project increases in correlation with the velocity of the available hardware. This raises the question on how the simulation can be more effective in respect to the use of personnel.

Thus, the qualified user needs a tool that helps him to implement his knowledge in the areas of error diagnostics and optimization. This ‘second generation’ of simulation tools (G. Hartmann, R. Seefeldt, 2004) aims to use the knowledge of the user to formulate the purpose of optimization and assessment criteria for the simulation process. The above mentioned steps of a single simulation project (change of CAD-geometries, process parameters, start of a simulation, and evaluation of the results) can indeed be carried out by a computer according to appropriate pre-settings.

The rapid development of computer processors and memory generates increasingly powerful hardware. Today, it should be possible to simulate hundreds of variations of a casting process overnight. However, the definition of these variations would take some time and the amount of generated information could hardly be evaluated within days. The advantage of the very short computing times can only be used if the evaluation and the new definition of the calculated variations would be carried out automatically by the computer. Basically, there are two different approaches.

On the one hand, there are knowledge-based systems that perform modifications or optimizations of the casting process based on stored regulations. However, a very high number of clear and unambiguous correlations between cause and effect need to be known for that purpose, which is not the case in high pressure die casting.

On the other hand, there is the possibility to use the survival of strong individual’s genetic components as it is practiced in nature. Genetic algorithms accept variations more or less at random where reasonable variations survive from generation to generation.

The integration of such optimization algorithm into casting simulation software results in a system that is able to perform computerized and fully automated optimizations of the casting process. Basically, this system is suitable for the solution of the following problems in high pressure die casting:
Gas pores in the casting
Due to turbulences and dead areas, gas is entrapped in the melt before the actual die filling. Purpose of optimization is the minimization of peak gas pressure during filling. The variables are the parameters of the CAD-design of the runner.

Die lifetime
High temperature gradients that develop during the casting cycle in the die reduce the lifetime of the die. Purpose of optimization is the minimization of temperature gradients at certain locations of the die and at certain times of the casting cycle. The variables are the parameters of the CAD-design of the cooling/heating lines.

Use of dry die agents
Dry die agents in a closed die need to evaporate in the shot chamber and to re-condense at the wall of the cavity. Purpose of optimization is to keep the temperature of the die surface on the level required for this process. The variables are the parameters of the CAD-design of the cooling/heating lines, too.

Local squeezing
Many castings have heavy sections between thin sections. In order to avoid shrinkage cavities it is necessary to perform local squeezing. Purpose of optimization is to avoid heavy sections with pores. The variables are the exact position and the volume of the squeezers as well as the exact point in time, when the squeeze pin is pressed into the solidifying melt.

Fig. 1: Operational sequence of a numerical optimization by combination of casting simulation software with optimization software (in this case MAGMASOFT® with modeFRONTIER). Basis for the first statistical evaluation is the starting sequence. In the following, casting simulations are run for a specified number of generations each with a certain number of individuals. The results are evaluated after each simulation. Depending on the results the program determines new versions according to genetic principles.

Die filling simulation
The die 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 fibers) 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.
**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 ingate velocities need to be met.
- 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 (Fig. 2 through 5).

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**Fig. 2:** Turbulences in the gate due to unfavorable design.

**Fig. 3:** Disadvantageous dimensions of the runners lead to uneven die filling. Due to the tight dimensions the right branch of the gate is filled too late.

**Fig. 4:** Fan ingate, where the flow velocities vary considerably.

**Fig. 5:** Here, the ingate velocities are just right (40m/s).
Consideration of casting parameters

The die filling is primarily determined by the defined shot parameters. Thus, the plunger velocity and switching points need to be considered very precisely for the simulation (R. Fink, 1999). Generally it is assumed that the machine hydraulics is able to implement the defined parameters. In this case the volume flow of the melt as a function of time is exactly known and will be considered in the calculation accordingly (Fig. 6).

Using the PQ²-diagram, it can be verified if the machine hydraulics is able to convert the defined parameters (Fig. 7). The PQ²-diagram is calculated from the following parameters; firstly, the machine parameters that can be stored in the data base of the simulation program, classified under the corresponding machine types; and secondly, the tool parameters that are calculated from the CAD-model of the die. With the verified parameters the simulation program is able to calculate (and if necessary to optimize) various process values like filling time, gate velocity, necessary closing force, etc. (Fig. 8).

Fig. 6: The filling process in the simulation can be controlled by various shot profiles. This example shows a shot profile with constant plunger velocity in the first phase and a shot profile optimized according to NADCA. Based on the defined machine and die parameters, the simulation program is able to calculate an optimized shot profile.

Fig. 7: With the PQ²-diagram, the optimally adjusted operating point for machine and die can be determined.
Identification of casting errors due to suboptimal filling

The results of the mold filling simulation allow an evaluation of the chosen casting parameters and the runner in respect to the anticipated quality of the casting. The typical casting errors due to suboptimal filling are visible welding lines, cold runs, or pores as a result of entrapped air. With the help of mold filling simulation it is possible to verify the formation and development of those errors (Fig. 9 and 10).

Errors like erosion of the mold are caused by the filling process, too. Generally, erosion is a result of high melt temperatures in connection with high melt velocities. Those conditions usually occur at the gate but also at positions where the melt is redirected (Fig. 11).

Fig. 9: The simulation can precisely predict stretcher lines and cold runs at thin wall castings.

Fig. 10: Gas can be entrapped if the venting doesn't conform to the die filling. The pressure of entrapped air at the end of the filling results in gas pores.
Fig. 11: Just before the ingate, the pressure is especially high during filling. This results in high wear in this area of the die.

Ideally, the die filling process is directed in a manner that the casting can directionally solidify towards the biscuit. At the same time, the volume of the gating system should be reduced as much as possible. It is often required to have a certain area of the casting with a minimal amount of entrapped gas. For this purpose the location or the design of the runner and gating system is modified, where the simulation verifies this alteration.

Simulation of the casting solidification

The solidification of the melt is characterized by a number of metallurgical-physical phenomena that eventually determine the local properties of the casting. Those need to be considered in the simulation with appropriate modeling approaches. The main aspects in high pressure die casting are the shrinkage during solidification and the microstructure formation.

Shrinkage during solidification

The volume contraction during the solidification of the metal melt leads to shrinkage cavities and dispersed porosity depending on the alloy and the wall thickness of the casting. Heavy sections of the casting usually form a stable metal skin, whereas thin walls and especially the ingate start to freeze quickly. For this reason, feeding can only be used as a compensation of the shortfall in volume if the ingates are thicker than the wall of the casting, where further feeding is necessary (exception here is local squeezing).

The simulation allows an easy determination of areas where solidification shrinkage can lead to volume errors (S. Kluge, 1999). The simplest criterion is the solidification time (Fig. 12). The possibility to partially compensate the solidification shrinkage by feeding with the plunger or with the local squeezer can also be displayed (Fig. 13).

Fig. 12: Dispersion of the solidification times in a gear box housing with different wall thicknesses (left) and in a structural component with constant wall thicknesses (right). Long solidification times indicate shrinkage errors.
Correlation of calculated and measured porosity

In the past years, computer tomography (CT) has been increasingly used in the area of quality assurance. As imperfections can be exactly localized and results are very accurate, the computer tomography is a great support for casting simulation (Fig. 14).

During the development of a gear box casting some cast prototypes were analyzed with the help of CT. At the same time, the casting process was simulated. The comparison of the results shows a vast agreement between the measured and the calculated pores.

Local squeezing

Shrinkage cavities are acceptable in some die castings; however, they generally cause problems during mechanical exposure and during machining of the casting. Shrinkage cavities always occur in heavy sections that are functionally necessary in many die castings. There are only a few possibilities to avoid shrinkage cavities, if the design of the casting can’t be modified. One of those possibilities is local squeezing.

The example in Figure 15 presents the dimensioning of a squeezing system that should be used for the forced feeding of a critical area in the casting (Fig. 15).
Purpose of optimization is to completely feed the critical heavy sections with a small volume squeezer (Fig. 16).

Fig. 15: The maximum solidification time occurs in a thick-wall area of the casting. This certainly leads to distinctive shrinkage cavities. As feeding is not possible in this area a local squeezer needs to be used.

Fig. 16: Depending on the design of the squeezing system, shrinkage cavities can be avoided at the critical area (right). Location and volume of the squeezer as well as exact point in time of the squeezing need to be determined. As shown in the left figure, insufficient parameters do not lead to the desired result.

**Microstructure formation**

The microstructure formation is depending on the alloy and on the local solidification conditions. A consistent solidification structure or structure after heat treatment can only be assumed for castings with an even wall thickness. All castings with different wall thicknesses inevitably show a distribution of various microstructure characteristics and thus have different local casting properties. The simulation of microstructure formation differentiates between macro- and micromodeling. Using macromodeling, microstructure characteristics can be derived from the results of the heat flow calculations. For instance, the secondary dendrite arm spacing of many aluminium alloys can be calculated from the local cooling rate and the temperature gradient (Fig. 17). The calculation of the formation of grains, eutectics, or microscopic gas precipitations can not be implemented in praxis yet. This calculation is often based on two-dimensional calculations in microscopic scale and currently serves mainly as an instrument for the understanding of the microstructure formation.
Simulation of residual stresses in castings

Basically, in every casting with different wall thicknesses occur residual stresses. Different wall thicknesses of the casting lead to different cooling behavior after pouring as well as after heat treatment and thus result in residual stresses and in distortion of the casting (A. Egner-Walter, 1999). Usually, this distortion lies in an acceptable range. However, the existing residual stresses can lead to a different behavior of the casting under load. In material pairs like aluminium cylinder crank cases with cast iron sleeves, massive residual stresses can occur due to the different expansion coefficients, too (L. Kallien, R. Rösch, 1999).

Models and their validity

The basic problem in the process of calculating residual stresses is the determination of laws to describe the material behavior in high temperatures. The creeping phenomenon at high temperatures, as well as the contact between die wall and casting, are often inaccurately described. These effects are currently subject of intense research projects (G. Hartmann, 2005).

Therefore, the technical calculation of residual stresses is primarily based on the cooling of the casting after ejection. Regarding the processes taking place in the closed die, it is assumed that arising stresses in the casting are plastically relieved. Thus, the free shrinkage of the casting is calculated.

Evaluation of residual stresses and distortion

The locally arising von Mises equivalent stresses can be used for the evaluation of residual stresses. This equivalent stress is determined as vector product of the arising three-dimensional stresses. The development of residual stress until the removal of the ingate is initially calculated based on the results of the solidification simulation and during the cooling of the casting. Depending on the proportion between cross section of the ingate and wall thickness of the casting, the removal time of the ingate has a significant influence on the development of residual stress as this process leads to stress transfer in the casting (Fig. 18). Due to the occurring stress transfer, machining of the casting can also lead to distortion (Fig. 19). The finally important value is the distortion caused by the residual stress in the machined casting (Fig. 20).
Fig. 18: During the removal of the ingate, stress is transferred in this thin-walled magnesium casting. The stresses in the indicated area are in the range of 20MPa before the removal and are nearly relieved after the removal.

Fig. 19: During machining of a casting, stress transfers occur due to the removal of stress-loaded material. The casting (left) indicates more stresses than the machined part.

Fig. 20: The overall distortion of the machined part is an important quality feature. If the distortion of the casting after machining is outside the acceptable range, the casting needs to be remounted and machined in multiple steps. The raised image allows a qualitative evaluation of the distortion. Accurate dimensional discrepancies that are in this case in vertical direction to the mounting plate can additionally be color-coded.

Simulation of stresses in dies

Stresses in dies are basically caused by the following three reasons:
- The load caused by the closing mechanism of the machine,
- The load caused by the melt that is highly pressurized at least for a short moment in time, and
- The cyclically changing temperatures in the die segments that lead to cyclically changing residual stresses.

These conditions cause a highly complex and unsteady overall load, whose entirety is difficult to display in simulations, but where the single elements can be measured quite accurately (C. Rosbrook et al., 2000).

Stress and distortion in the die frame

The simulation of stress and distortion in the frame is always advisable when huge castings like engine blocks or castings with a large projected area, like structural components, are combined with tight die tolerances (due to dimensional limitations of the machine). At complex, i.e., entire models with side cores (Fig. 21), an initial stress value is assumed at the side core locks (Fig. 22). It can be assumed that there are little temperature gradients between the frame and the insert.
If the die spotting was carried out in a warm environment, the thermal residual stresses especially in the die inserts have nearly no influence on the stress in the frame (Fig 23). Closing force and pressure of the melt as well as a stable temperature of the frame are considered for the examination of the distortion in the frame.

Fig. 21: A complete model including all die segments is created in order to calculate the load of the frame.

Fig. 22: Stresses in the frame due to initial stress at the side core locks.

Fig. 23: Die spotting should be carried out at elevated temperatures. In this case stress in the operating frame is much lower (left) than when it was performed in a cold environment (right).

Stress and distortion in the die inserts

For the evaluation of stress in the inserts, the thermal residual stress is a considerable part of the overall load. The thermal shocks in each cycle caused by the melt and later by the die agent in correlation with the die tempering generate inhomogeneous and cyclically unsteady temperature distributions with partially very high gradients. This results in thermal residual stresses, where a likewise cyclically changing distortion is especially important for the lifetime of the die insert. These calculations need to be carried out with non-linear, elastoplastic model approaches, too.

Temperatures in a die casting tool can differ significantly. High pressure die casting dies in Aluminum applications can reach temperatures of more than 450°C near the impressions just after the filling. Temperatures close to the cooling channels are much lower (Fig. 24). Due to the temperature gradients appearing in all high pressure dies, residual stresses arise especially in the die insert, where the tool steel load can reach the yield point (Fig. 25). Compressive and tensile stresses successively occur due to strong temperature changes that are also caused by spraying of die agents. This leads to the development of cracks, especially in slim cores, where big changes in temperature happen due to intense heating up and cooling (spraying).
Integrating the casting simulation into development and manufacturing

A lot of information is generated during casting simulation, a lot of which would not be available when using conventional processes. To what extent this information can actually lead to a measurable improvement of casting design or processes is depending on the level of integration of the simulation into development and manufacturing processes (H.-G. Haldenwanger, 2000, G. Hartmann et al, 2000, E. Beutner et al., 2001, W. Sequeira et al., 2002). In this respect, we can differentiate between firstly technical integration with focus on the communication of CAE-tools via interfaces, and secondly structural integration with focus on information management during planning and performance of operating procedures.

Technical integration of the casting simulation

The information generated by the casting simulation is of significant importance to the constructing engineer. The local properties of the casting, like microstructure distribution, mechanical properties, or casting errors can be calculated and displayed with the help of casting simulation. Whereas the calculated distribution of casting errors is only a qualitative approximation of the local damage of the casting, FE-calculations can consider calculated, local, mechanical properties (T. McMillin et al., 2002). There is the fundamental problem that different simulations, like the casting simulation and FE-analysis or crash simulation, are carried out with different calculation meshes. One mesh of a die-dashboard for casting simulation consists of two million elements whereas the mesh of the very same part for crash simulation consists of only some hundred nodes. Thus, interfaces need to be used that transfer the calculated and interpolated value fields from one calculation mesh to the other.
Structural integration of the casting simulation

Data and information are increasingly valuable once they are used in praxis. In the foundry, technologies like charge material calculation, thermal analysis, spectral analysis, analysis of the gas concentration, x-ray, or CT provide information, whose flow and use is determined by QA-processes. In the same way it needs to be dealt with data generated by the casting simulation, that only gain in value when implemented into design and manufacturing (A. Schroth, D. Schemme, 2002). There are no standardized rules in respect to the integration of casting simulation into design and manufacturing processes. However, companies with good experience in casting simulation exercise binding rules regarding the integration of simulations into existing QA-structures. Generally, the following is determined:

- Projects, where a casting simulation needs to be carried out,
- Point in time of the simulation,
- Charged cost centers,
- Documentation and back-up of the simulation results,
- Responsibility for optimization measures based on the simulation, and
- Verification of the optimization measures.

A steady improvement of development and manufacturing with the use of casting simulation can only be assured where work processes strictly follow such binding agreements.

Use and restrictions

Commercial programs for simulation of casting processes have been on the market for nearly 20 years now. Performance and credibility of software and available hardware have been drastically expanded and improved in this time. In some casting applications, like steel casting, the use of simulation had been evolved very quickly and reached a high level ten years ago. Today, there is hardly any steel casting with corresponding casting process that has not been extensively optimized with the help of casting simulation.

On the contrary, the utilization of casting simulation in the design of high pressure die castings and die casting processes is much less than in steel casting. In the light of the global competition, especially by Asian foundries that are producing with drastic cost advantages and rapidly improving technology and equipment, as well as increasing know-how, the following perceptions exist in the western countries:

The cost of the simulation is too high.
The costs of a high pressure casting die in relation to the costs of a pattern for a sand casting shows a huge potential to save costs if one succeeds in avoiding tool changes, in increasing tool lifetime, and in producing the desired quality of the casting at the first go. In many cases, costs for failed sample runs or for error correction and for rework are not consequently added to the unit costs. This results in high overhead costs that are considered as inevitable. Engineers and technicians are not exactly aware of these costs in detail and sometimes do not feel responsible for them. On the one hand, the management tolerates significant cost variances for single products, but on the other hand, the management avoids to either pay in advance for simulation or to approve expenses for improvements that assure cost reductions. The result is a declining competitiveness of the company. There is hardly a casting process, where effective and professionally used simulation is as beneficial as in high pressure die casting.

Up to now, solutions have been found without the help of simulation.
Foundries with a conventional and little changing range of products will find satisfactory solutions without the help of simulations. However, in this case simulations could help to reach improvements in a quicker and more methodical way. As the automotive industry requires a yearly price reduction for repetition parts due to constant operational optimization, room for improvement needs to be detected by simulation, and effectiveness of these improvements need to be evaluated by calculation. Everything can be tried in a simulation, including variants that are finally not implemented into the
real process. For sophisticated castings, it is important that provider as well as customer know as early as possible about the reliability of the planned casting technique.

**The simulation doesn't present the exact reality.**
The validity of the physical-mathematical models as basis for the simulation has been proven in many successful projects. It is often difficult to find the exact manufacturing process conditions of a casting. In this case assumptions need to be met, where the detection of useful variations finally leads to a good agreement between the real conditions of the casting and the simulation values. This is the basis for the improvements achieved by the implemented changes. The experimentation is carried out in computerized manner. Due to the high number of parameters in high pressure die casting there are phenomena that appear in reality but are not part of the simulation model. Based on simulations, many companies have significantly improved the accuracies of new parts so that already in the first sample line high-quality parts are produced followed by a consistently top-quality serial production.

**With simulation, knowledge can easily be transferred and know-how based on experience has less value.**
It is difficult to defend the competitiveness of a company based on the specific knowledge of certain employees. There is probably a higher loss of this knowledge due to employee turnover than due to the transfer of simulation results between designer, foundryman, toolmaker and end user. The work of casting service providers is based on confidentiality. It is proved that simulation in one's own company leads in any case to increasing know-how rather than to the loss of technical expertise. Knowledge can be stored and internally transferred by using documentation and archiving processes. In this way, personal knowledge is much better processed and actually made available to other employees. The quality of the calculated results is significantly improved when considering know-how based on experience in the simulation. Now and in the future, the foundry specialist is needed.

**There is no use of simulation in my area of responsibility.**
No question, 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 manufacturing 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 endeavor 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 doesn’t 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 their own interest, foundryman should be involved in and pro-actively work on the processes as early as possible.

Alfred T. Spada, editor of ‘Modern Casting’, writes regarding the reservation towards the simulation in an editorial of ‘Modern Casting’ (A. T. Spada, 2004):
‘If you are still waiting for casting process modeling/simulation to prove itself, I’d say that your are at least a decade behind the times. If you still argue that you can’t justify the cost for the technology/manpower, I’d say that you haven’t done a true time or cost analysis as to what this software can save your operation. The proof is in the success that every metalcaster using the technology has had.’
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