Optimization of HPDC Process using Flow Simulation - Case Studies

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Abstract

This paper will highlight some of the case studies, where the flow simulation results helped in the HPDC optimization process in terms of various approaches viz., Failure Mode Analysis, Product Design Improvements, Cause and Effect, Design Simplification, Alternate Designs, Fixing and Revision of Acceptance Criteria, New Concepts, thereby giving CRP many solutions and its customers a lot of satisfaction.

Introduction

CRP (India) Private Limited is a leading manufacturer of High Pressure Die Casting Products in India. It was founded in the year 1975 by Mr. N. Kunchithapatham, one of the country's pioneers in the field of die casting in terms of design and manufacturing of HPDC dies, as well as production of castings.

CRP is a one-stop solution provider for the HPDC products, having expertise in the product design, die design, die manufacturing, die casting, machining, surface finishing, powder coating, assembly and testing.

The vast experience and the effective use of various tools such as CAD/CAM and flow analysis has made CRP a pioneer in this field.

CRP has joined hands with Twin City Die Castings Company (Founded 1919) of USA in September 2009 to promote a joint venture in India viz., CRP-TCDC Die Castings India Private Limited (CTI), in order to cater to the growing needs of technical and engineered die castings.

Having seamlessly integrating flow analysis into its design process and completing hundreds of simulations so far, CRP has a lot of experience and wisdom to share with the user community.

This paper will be a continuation of the paper #102 presented at 113th Metal Casting Congress that was also published in the July'09 copy of the NADCA's Die Casting Engineer.

The paper will highlight some of the new and more interesting case studies, where the flow simulation helped in the HPDC optimization process in terms of:

- Failure Mode Analysis,
- Part Design Improvements
- Cause and Effect
- Design Simplification
- Alternate Designs
- Fixing and Revision of Acceptance Criteria
- New Concepts

Case Studies

The following case studies explain the various approaches towards the application of flow simulations in HPDC Process.

Case Study One: Failure Mode Analyis

The first three case studies are pertaining to a very critical part - a crank case used in an automobile compressor application.

During the production process, the die was found to wear very frequently resulting in high rejection rates, frequent breakdowns resulting in interrupted production for die maintenances.

The process audit revealed a very high injection velocity of more than 2 m/sec whereas the theoretical velocity needed was less than 1 m/sec. This high velocity results in a very high gate velocity, thereby causing the rapid die erosion especially near the gate area (Figure 1a).

The design of the experiment revealed that the high velocity is required, without which the part will not fill properly. On the other hand the part geometry does not allow any more increase in gate area, creating a deadlock situation.

Figure 1a – Moving Core of the Die showing high wear near the gate area.

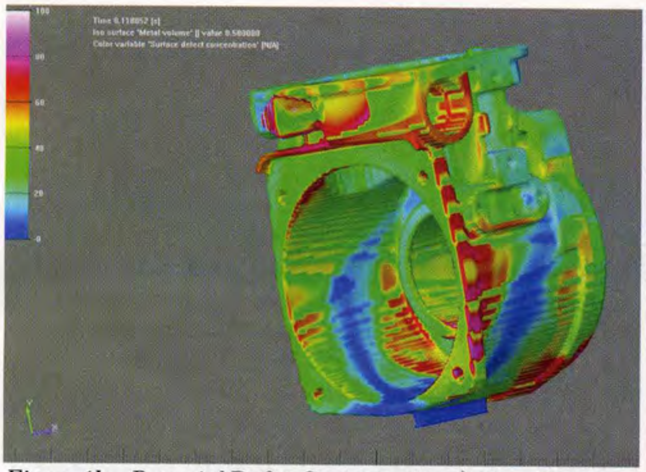


Figure 1b – Potential Defect Concentration at theoretical velocity of < 1 m/sec.

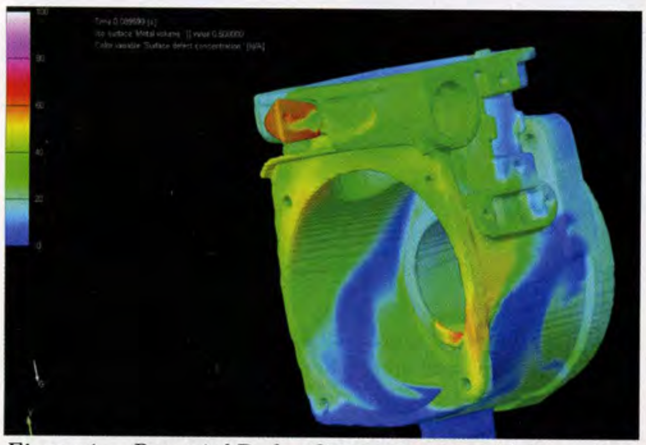


Figure 1c – Potential Defect Concentration at higher velocity of > 2 m/sec.

The flow simulations for defect predictions were done for velocity of 0.8m/sec (Figure 1b) and 2.2m/sec (Figure 1c).

The effect of the high velocity filling was very clear from the results, and it correlated with the process parameters, hence confirming that this part design requires such a short cavity filling time.

Discussion with the customer, based on the results of the simulations, resulted in the following decisions:

- to change the moving core portion of the die at a frequency of every 25000 shots.
- to work together to improve the Part Design and reduce the filling velocity.
- to revisit the acceptance criteria without affecting the form, fit and function of the part, considering the intricacy of the part as revealed by the simulation.

Case Study Two: Part Design Improvements

This case is a continuation of the previous one, in terms of the design improvements as suggested by CRP.

Upon close examination of the design and the part drawing, it was found that the general radius was called for as 1.6 mm, whereas in the design, as well as in the actual part, a general radius of less than 1 mm was maintained. This was requested by the customer to give a better aesthetic to the part.

It is a well known fact that the increase in the radius will contribute towards improved flow, thereby mitigating the

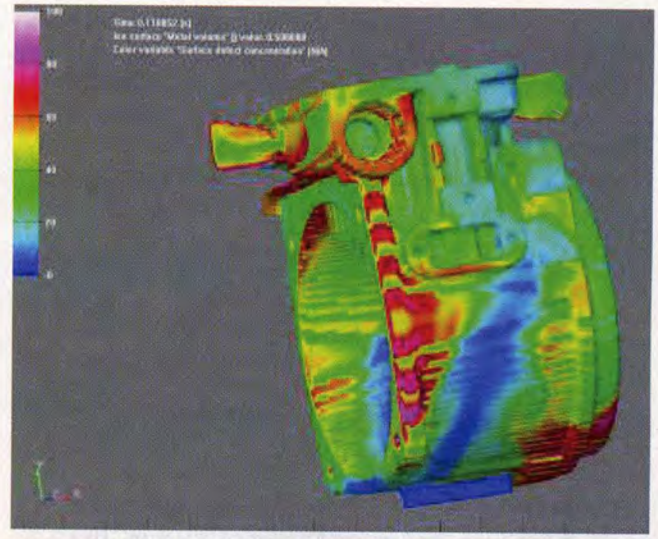


Figure 2a – Potential Defect Concentration with Existing General Radius of 1.0 mm.

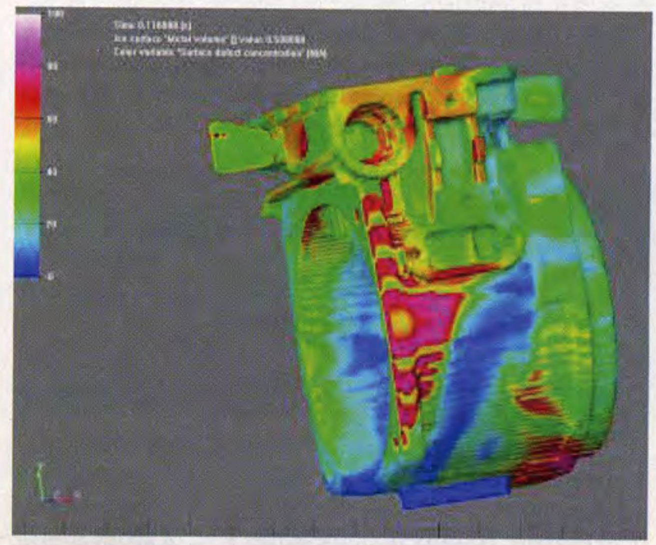
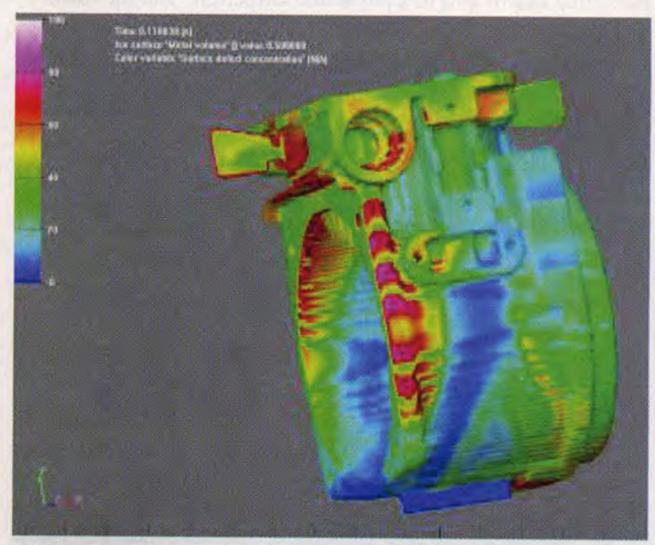


Figure 2b – Potential Defect Concentration with Specified General Radius of 1.6 mm.



Figrue 2c – Potential Defect Concentration with Suggested General Radius of 2.0 mm.

flow problems. It will also enhance the strength of the part, as well as reduce the damage during handling and use.

Flow simulations were carried out in order to find the effects of various general radii, including the existing radius of 1 mm (Figure 2a), the design specified radius of 1.6mm (Figure 2b) and the suggested radius of 2mm (Figure 2c).

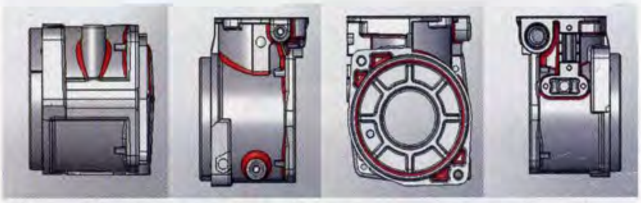


Figure 2d – Suggestion for radius improvements at various places.

The results helped CRP to persuade the customer to agree on the suggested general radius of 2.0 mm. This was implemented in the new die, resulting not only in the plunger velocity reduction from 2.2 to 1.5 m/sec, but also resulted in the reduction of process rejection from more than 25% to less than 7%.

It was a different story altogether when the same customer appreciated the new design for its better aesthetics due to the improved radius (Figure 2d). At last it was a tale of "radius conquering the sharp edge."

Case Study Three: Cause and Effect

This case is also a continuation of the previous two, in terms of cause and effect correlation and acceptance criteria.

Porosity was always an issue since the beginning of the development of this part, as it is needed to be pressure tight. But the intricacy of the part and the porosity requirements coupled with the design issues discussed in the previous two cases were already causing heavy rejections.

One day during the course of the above improvements, we received a SOS quality alert from the customer, claiming that there was a sudden spurt of rejection levels to more than 65% due porosity from the earlier level of about 20% in the previous batch.

The process audit found the surge of defects was attributed to a particular cored hole in the casting that was too deep in a particular depth and in a particular direction. The die history revealed that there was a request from the customer to change the cored hole from the existing 4.5 Dia to 3.5 Dia, to solve a position issue in the machining of the part.

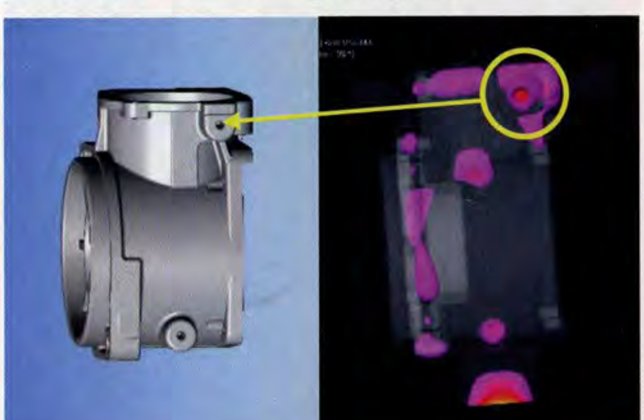


Figure 3a – Correlation of Part model (left) and simulation result (right).

As we suspected, the issue may be pertaining to shrinkage porosity in the hole. A solidification simulation was carried out.

The simulation categorically revealed that there is a potential shrinkage porosity issue at the location (Figure 3a) and addition of machining stock of 1 mm over the diameter is not at all recommended.

Even though the customer refused to buy our idea initially, they were forced to revert back to the original core diameter of 3.5 mm upon seeing the simulation results. The batch produced immediately after the core pin change had a porosity level of around 15% which clearly vindicated our stand and resolved the issue and cleared our name.

This has also resulted in the customer having a more pragmatic look at acceptance levels and relaxed the acceptance criteria in terms of porosity without compromising on other requirements, including the leak. And the new level of acceptance reduced the defects to less than 5%, making the part more viable and interesting to produce.

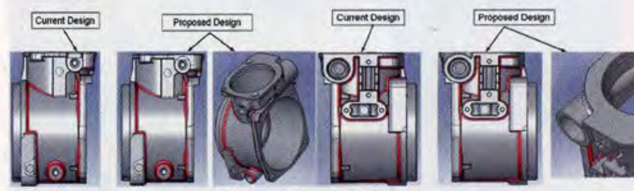


Figure 3b – Suggested Part Design Improvements.

To mitigate the porosity levels and flow related issues CRP has suggested more part design improvements (Figure 3b) focusing on further radius improvements at specific areas and avoiding uneven wall thicknesses.

Case Study Four: Design Simplification

Reducing the cost is the need of the hour, and the design simplification is one of the effective means. This case is an example of the same where as the customer requirements in terms of volumes have increased and adding capacity at this juncture should be the last option. Hence we explored the possibility of cycle time reduction through simplifying the design.

This part design needs a hydraulic sliding core for a hole (Figure 4a) and the added complication of a submerged core resulting in intricate matching areas. Due to this, the die opening and closing needs to be slow, and coupled with the hydraulic core movement, the cycle time was high. There is also a constraint for a multi-cavity design approach.

Removal of the sliding core will be a solution, but there may be chances of high porosity if the solid hole is drilled

Figure 4a – Model of the part showing the cored hole.

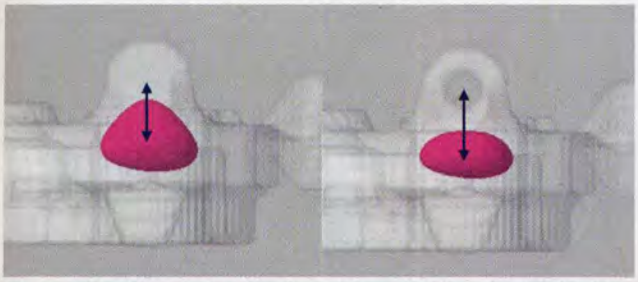


Figure 4b – Simulation results without (left) and with (right) the cored hole showing the hot metal areas.

and tapped. This is a mating part of the previous examples, and porosity is a stringent requirement.

Therefore a solidification simulation was carried out to compare the effect of removing the core in terms of porosity location.

Figure 4c – Model of the part without the cored hole.

Even though the result showed a significant shift of the center of the hot metal (which may result in porosity), it was away from the cored hole by more than 10 mm (Fig 4.2). So a new die was developed without the cored hole (Fig 4.3), and the drilling operation was introduced before tapping in the VMC. This has resulted in an overall increase in throughput.

The cost of die was reduced significantly, and PDC machine tonnage is also reduced, resulting in cost savings. Now, with the elimination of core and design simplification, CRP has developed a multi-cavity tool to augment the throughpout further.

Case Study Five: Alternate Designs

Certain part designs will remain a challenge to be produced, and it evokes a lot of effort from the designer's point of view. One such case is considered here, wherein the simulation results helped in persuading the customer to accept the alternate designs in order to make the parts much easier to produce, and to improve the yield.

The part discussed in this case is of a luminary application and has high aesthetic requirements. The part is flat on all sides, has very little to no radius, and has a 0.5 mm step with sharp edges, to be preserved throughout the production process.

Adding to the challenge, the feeding points are restricted to one surface only, and no gating points are allowed for venting or overflow pads.

Simulations were done with and without vent and overflow pads. The results indicated a significant improvement in terms of reduction flow defects in the case of shot with vent and overflow pads (Figure 5a).

Initially the customer was hesitant to accept the modifications as they were concerned about the removal of the gate marks during finishing operations. CRP developed and demonstrated an effective method to finish the part by use of a sanding operation with a fixture, resulting in the customer accepting the proposed design. CRP can substantially reduce the reject levels from the existing level of more than 40%, if not eliminating it.

Case Study Six: Fixing and Revision of Acceptance Criteria

It is always desirable to fix acceptance criteria for porosity at the beginning of a product life cycle. But most of the time it is difficult to implement, as it is not easy to estimate and fix the extent and locations of the defects. Here is one such case where the simulation results in correlation with the actual defects were used to fix the acceptance criteria with the customer. The part is a thermostat housing for an automobile application.

Once the bulk production started, the porosity levels were found to be very high, especially in two areas. First is the area were a 3mm depth groove is machined on an internal diameter surface. Second is the area where an angular solid boss is machined by drilling and tapping.

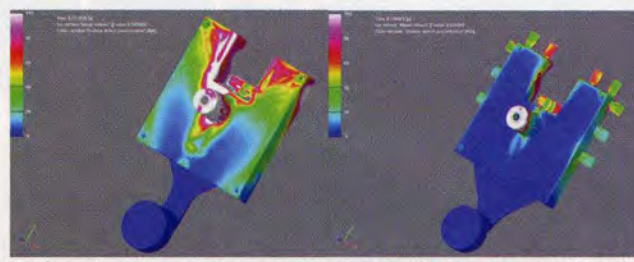


Figure 5a – Simulation results without (left) and with (right) the vent and overflow pads.

The 3mm groove area porosity was due to flow defect concentrations as revealed by the flow simulations (Figure 6a). It was also easy for the customer to see that this porosity will not affect the product requirement at it is only a recess for a circlip.

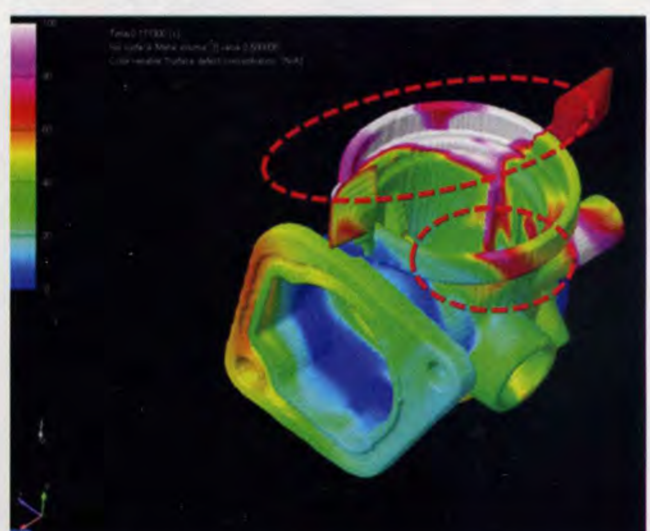


Figure 6a – Flow Simulation results showing defects concentration in the Groove machining area.

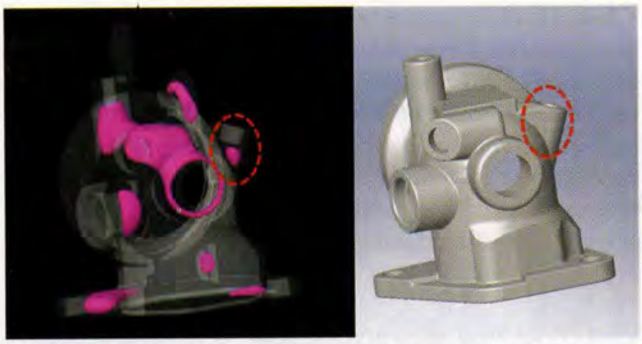


Figure 6b – Solidification Simulation results showing hot metal at the angular solid boss area.

The angular solid boss area porosity was due to shrinkage, as revealed by the solidification simulation (Figure 6b). It was also clear that this porosity will not result in any leakage or breakage.

In both the areas, the correlation of the results and the actual defects were spot on. Part design and die design options are ruled out and hence mutual acceptance levels has been arrived at and agreed upon with the customer.

Case Study Seven: New Concepts

Everything around us changes rapidly and outside-the-box thinking is the order of the day. Lateral thinking by the designers will evoke simple solutions, even for complex problems. This case is a typical example of that.

Using a chill is a common concept to avoid/shift porosity in gravity casting. One of the automotive application parts, an oil filter adaptor, which has porosity and leak proof requirements, was a challenge and CRP thought of implementing this "chill" idea.

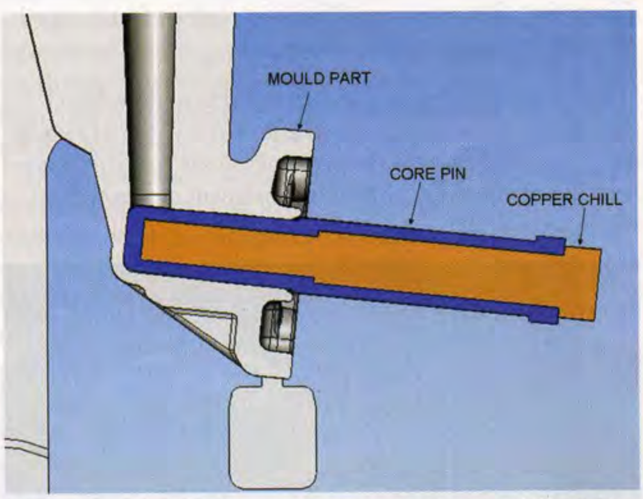


Figure 7a – Model showing the concept of copper chill within the core pin.

One of the critical bore areas of this part had the issue of last fill as well as shrinkage porosity issues. The core pin at this location was very small and cooling systems for it was complex and costly. Therefore it was decided to use a copper chill inside the core pin to rapidly take away the heat from the tip if the pin through the center portion (Figure 7a).

The condition was simulated with the emerging technique, called thermal die cycling simulation, and the results were encouraging (Figure 7b).

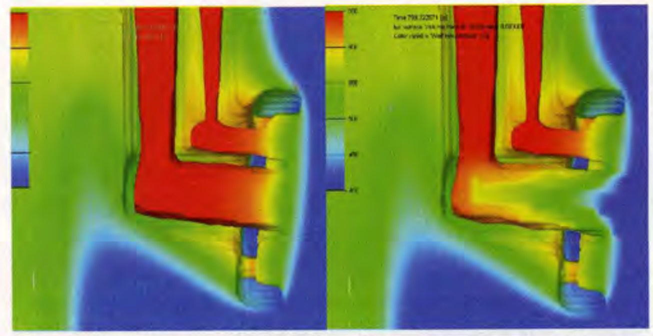


Figure 7b – Thermal Die Cycling Simulation results without (left) and with (right) the copper chill.

The chill was implemented and the actual measured temperature profiles of the core pin with and without chill were found within 20?C of the simulation results, and the correlation was amazing. The porosity levels were significantly reduced from above 20% to less than 5%.

The key aspect in this design was to ensure proper contact of copper with the die material on all sides and at all times. This was ensured in the manufacturing in order to achieve this remarkable result.

Conclusion

The rapidly changing world throws up lots of challenges and die casting field is no exception. Product life cycles are getting shorter and times are shrinking. But technologies and tools are emerging to face these challenges. It is up to us to find, learn, apply and master them in order to be successful.

CRP was able to apply the innovative use of technology coupled with the effective application of experience to achieve swift, efficient, and successful results.

The author hopes to rekindle a few thoughts by sharing these case studies in order to stimulate the use of simulations, and encourage other die casters to seriously try it themselves.

Let us pledge to save the earth for the future generations to come, by not contributing to waste and by contributing to the elimination of the waste, no matter what will be its form, shape or size, and by whatever it takes.

Flow simulations are definitely one of the effective means as far as die castings are concerned in terms of reaching this goal.

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