Simulation helps overcome challenges of thin wall magnesium diecasting

The benefits of using Flow 3D are described.

Computer simulation is playing a major role in reducing the weight of intake manifolds by making it possible to meet the challenges posed by thin wall magnesium diecastings. A wide range of problems, including the danger of solidification, oxide generation and air entrapment put major limitations on reducing wall thickness. These problems would be addressed in the past by a process of trial and error. However, it could take about six weeks to implement changes to the gate, runner and venting system of the production die and no one knew how many more changes would be required to achieve consistently high parts quality.

A few far sighted diemakers, such as Werkzeugbau Schaufler, Laichingen, Germany, have tackled this problem head on by using computational fluid dynamics (CFD) software to predict the performance of various die configurations on the computer. This approach can accurately evaluate the design and provide detailed information on conditions inside the die cavity that speed up the process of iterating to a solution. Using these methods, Werkzeugbau Schaufler has successfully produced 50 dies for different thin wall magnesium parts in the last few years to a high level of quality.

Schaufler ranks among the top European diemakers and specialises in manufacturing dies for aluminium and magnesium castings. Its facility covers about 50,000ft^2, providing the infrastructure for building dies up to a weight of 35 tonnes for transmission and clutch housings, body and structural parts, cylinder blocks and, last but not least, variable inlet manifolds. The company recently opened a technical centre to meet customers' demands for short development times and the elimination of sand casting patterns in favour of die diecasting prototypes. The Diecasting Center Laichingen (DCL) features an automated cell based on a Buhler SC 270N diecasting machine with a locking force of 2,700 tonnes, aluminium and magnesium furnace, SSM slug heating station, ABB spray and extraction robot, cooling basin and machining center.

Trend to thinner wall diecastings

In the last few years, Schaufler and other top ranked diemakers have been asked by automobile manufacturers to manufacture dies for thinner wall die cast components in order to pass on incremental weight savings to consumers. One of the most interesting examples of this trend is the move to thin wall magnesium variable inlet manifolds that combine weight savings with performance improvements.

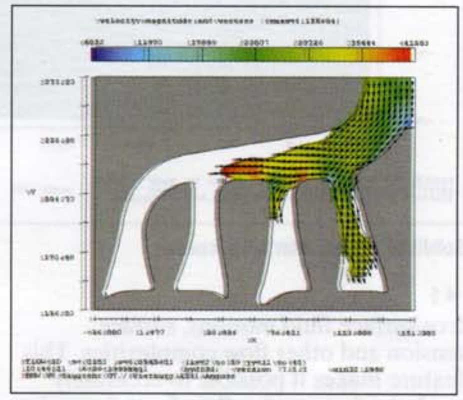
Casting of these parts is, however, a challenging task. Magnesium has a low specific heat content, significantly lower than aluminum, which means that it cools very quickly, running the risk of solidification during the filing process. This problem is particularly challenging when wall thickness is reduced to the 1.8mm to 2mm range, as has occurred with the most recent designs.

To avoid solidification problem, filling has to be performed with a high flow velocity, often 60m/s in the ingate and 100m/s plus in thin walled regions. Unfortunately, high flow velocity has the tendency to cause flow separation and vortices that in turn produce air entrapments that lead to porous regions and oxide generation.

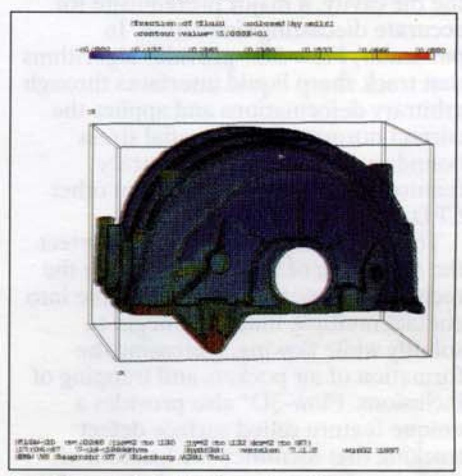
In most cases, these problems can be overcome by changing wall thickness or adding flow channels in suitable areas of the part. However, it is far from obvious where such features need to be added. In the past, the only way that die designers had to evaluate the effectiveness of a proposed change was to build a new die and test it out by producing parts. The parts were then x-rayed to determine whether they had internal flaws that would cause them to fail the automotive OEM's quality standards.

Previous difficulties and delays

The results of the testing provided little or no information on critical flow patterns during the filling process; engineers had to rely upon intuition and



Flow distribution in gating.



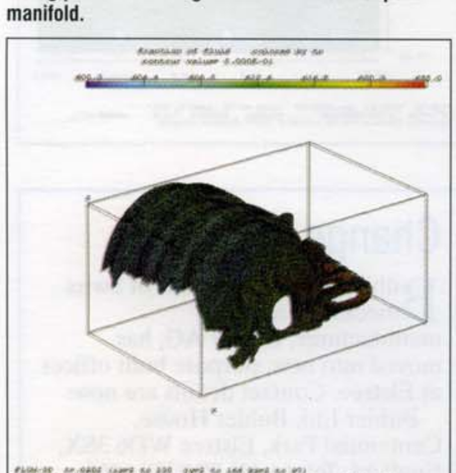
Impurities predicted by the surface defect mode.

change a few years ago as developers of CFD software began to provide features that made it possible for the first time to accurately simulate high flow rate diecasting operations. CFD involves the solution of the governing equations for fluid flow and heat transfer at hundreds of thousands of discreet points on a computational grid in the flow domain. When properly validated, a CFD analysis allows engineers to 'look inside the die' and determine the exact position of the flow front at any point in time, as well as the temperature and pressure of the metal at any point in the die. The geometry of the model representing the die can be changed quickly on the computer and re-analysed to determine the effect of the change.

Software designed for diecasting

Rolf Krack, process engineer for Schaufler has had excellent results using a CFD software package called Flow-3D® software from Flow Science, Inc., Los Alamos, New Mexico, that has implemented several important features designed to improve diecasting simulation. The first is the use of the volume of fluid (VOF) method to predict

Filling pattern of a magnesium variable inlet path manifold.



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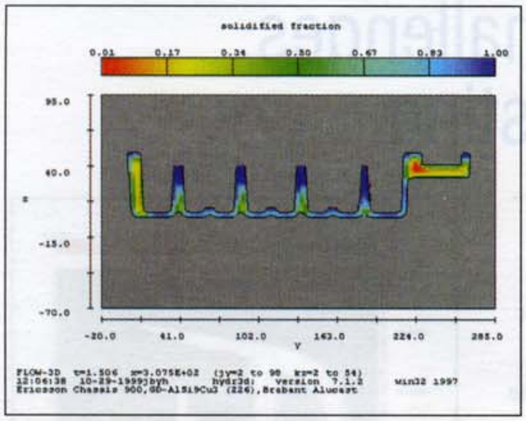

Solidified regions after 1.5 seconds.

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free surface fluid motions, surface tension and other flow complexities. This feature makes it possible to accurately track the fast moving flow front through the die cavity, a major prerequisite for accurate diecasting simulation. In particular, Flow-3D® provides algorithms that track sharp liquid interfaces through arbitrary deformations and applies the correct normal and tangential stress boundary conditions - an accuracy feature that distinguishes it from other CFD programs.

This makes it possible to easily detect the formation of vortices that cause the recirculating metal surfaces to come into contact multiple times and begin to solidify while flowing, increasing the formation of air pockets and trapping of inclusions. Flow-3D® also provides a unique feature called surface defect tracking that identifies the location of oxides and impurities at each stage of the filling process so that overflows can be sized and dimensioned appropriately.

As a typical example, Mr Krack used Flow-3D® to simulate the magnesium variable inlet path manifold for the current Audi V8 engine. "I started the simulation as early as possible in the design cycle so that any changes that were required could be made at a time when they were least expensive to implement," Mr Krack said. "I began by performing a flow analysis of the runner and gating system. The simulation results showed me areas of undesirable flow separation due to abrupt changes in cross sections and other flow features. I corrected these problems by making appropriate design modifications to the gating. Then I proceeded to simulate the filing of the part. This simulation took into account heat transfer to and heat conduction through the die, as well as solidification of the molten alloy, thus helping to detect areas of early solidification."

Looking inside the die

The simulation process made it possible for Mr Krack to do something that was never possible with physical testing - 'look inside' and view the flow of the molten metal throughout the part. The key factors that he considered were:

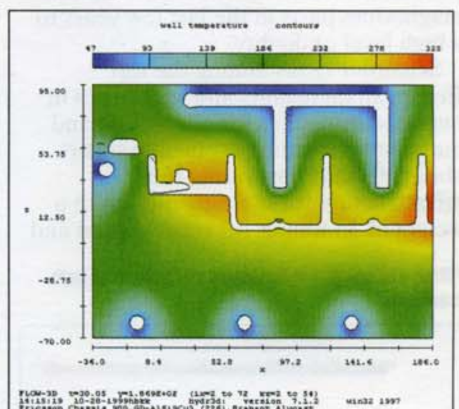
1) Is the part being filled continuously or are there regions that are filled much later than others?
2) Are there any air entrapments?
3) Are there any regions of flow separation or vortices?
4) Is the flow front moving continuously or it bursting and splashing?

"There were plenty of problems the first time I simulated this," Mr Krack said. "With the simulation, I could see exactly what was happening, try different design changes and very quickly determine what effect they had."

"Using the insight that I had gained," continued Mr Krack, "I was able to devise a strategy to correct them. Primarily it involved using flow channels and increasing or decreasing wall thickness to either eliminate the vortices or to move the voids and inclusions so that they flowed out of the overflow vents where they were of no concern to anyone. Since this was one of the first times that I had used the software, I was concerned about its accuracy. We ran a series of trials with the part filled only partially to a series of different levels and matched them against the simulation results. The software matched the tests nearly perfectly. This gave us confidence to build a prototype tool according to the design that we had developed using the simulation, and it produced excellent parts.

"Due to the success of this project, we made the decision to adopt these methods for all thin wall aluminum and magnesium dies. The result has been a series of successful projects, also for cylinder blocks and structural parts that have established our firm as one of the leaders in this exciting new manufacturing technology."

Temperature distribution in the die 30 seconds after start of filling.



Troubleshooting with Al Ex

Al Ex is a multimedia expert system aimed at increasing the performance and productivity of foundries.

The technical information contained in this software is based on the expertise and knowledge of specialists from a leading European foundry research centre - Le Centre Technique des Industries de la Fonderie (CTIF) whose laboratories are in Sevres, France. The software and presentation has been developed by Groupe Vision Interactif, which is based in Quebec City, Canada.

A true work tool this software enables operations personnel to:

- Visually identify non-compliance problems by 3D representation
- Determine the potential causes of the problem
- Identify the appropriate corrective actions.

Developed from a tried and true problem/solution instructional approach, Al Ex is both production software and an ongoing training system. User friendly and easy to learn, the software relies largely on the strengths of multimedia as applied to training. It features visual and technical graphics, together with 2D and 3D animations and videos. Al Ex's open architecture allows users to customise the software to meet the production needs of their company. In addition, it can store non-compliance problems within databases, thus allowing easy retrieval and analysis for quality management purposes.

Direct economic advantages are:

- Increased productivity
- Decreased production costs
- Decreased production scrap

Capitalising on people's knowledge is the cornerstone of increased competitiveness. Al Ex provides a system to efficiently accomplish that goal.

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Change of scene

Bühler Ltd, the UK arm of Swiss diecasting machine manufacturer, Bühler AG, has moved into new, purpose built offices at Elstree. Contact details are now:

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