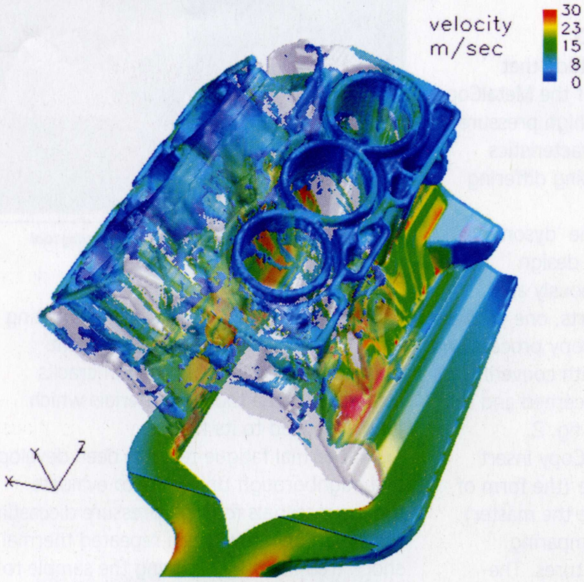
Dies & Tooling

Casting simulations speed up development



To produce highly sophisticated castings such as a V6 engine block, casting simulations must be applied in the development stage. Because of the complex component geometry, the die filling characteristics are very hard to assess on the basis of imagination alone. In such cases, simulations cut costs and save a lot of time during development

The close teamwork between Bühler engineers and customers makes computer casting simulations a very useful tool in diecasting.

Simulations allow parts to be developed within a shorter time and dies to be designed with higher precision, thus reducing the time needed until a die is ready for quantity production, which in turn cuts costs.

Cast components are expected to satisfy ever higher requirements, their development increasingly reaching the feasibility limits of diecasting. As a result, to survive in the marketplace in the long term, providers must use calculations and simulations at an early stage in the development process.

Bühler believes that its Die Casting Division gives customers the necessary competitive edge in all areas of diecasting by offering them computer simulation services and the correct interpretation of the simulation results.

Different opinions are desirable

Success can only be achieved by an entire simulation team, since individuals on their own are unable to perform simulations and evaluate them. The accumulated experience of team members involved in the analysis is also an invaluable asset.

To design successful dies, the Die Casting Division relies on specialists from the fields of process technology, die making, metallurgy and simulation. In the ideal case, the team will also be able to influence the geometry of the component to be cast.

Different opinions are desirable in team discussions, as nobody has a total view of things and minds must be joined to arrive at new insights. Should the team members fail to agree on a particular solution, Bühler will conduct variant studies. This juxtaposition of different solutions reveals the useful ones. But the others are just as valuable, since they add to the accumulated experience of the team members.

What is the use of simulations?

Ideally, calculations should start at the earliest stage possible in the die development process, as changes become increasingly difficult to make as development work progresses.

Many customers need support in calculating the die filling and solidification process or in connection with simulations to find out what happens inside the shot sleeve. The simulation programs applied by Bühler provide an answer to a large number of casting related questions. It is also possible, on the basis of the temperature fields in the cast components, to obtain indications of casting distortion problems.

Casting simulations provide the Bühler team with valuable information on die design. By optimising the design of dies on the basis of this information, costs can be reduced and time can be saved when starting volume production.

During this phase, each day available for smooth production will contribute to the financial success of the project. Computer simulations are therefore a valuable tool for speeding up the development of parts and producing them with high precision. The simulation team also offers consulting on feasibility during the initial phase.

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Loughborough research

The diecasting tooling work conducted by the Rapid Manufacturing Research Group at Loughborough University has been based on developing alternative methods of manufacturing tooling employing rapid prototyping methods such as selective laser sintering (SLS), direct metal laser sintering (DMLS), laminate tooling, Metalcopy etc.

From initial research it was clear that the materials suffered from thermal fatigue when subjected to the thermal cycles associated with aluminium diecasting. This lead to research with the aim of understanding the thermal fatigue failure modes of the rapid prototyping materials i.e. are the material notch sensitive, how do the cracks propagate, how many cycles does it take to initiate a crack?

It is anticipated that obtaining this information will aid rapid prototyping material development and it increase rapid prototype die life.

where low volumes are involved as time and flexibility is of the essence.

Within this 'rapid tooling' field of research, there are several methods being developed, one of which involves the use of powder binder mixtures to produce metal tooling.

A technique to form solid geometries from a metal powder has been developed by the Swedish company, Prototal AB, the process providing the opportunity to create tooling inserts as a rapid tooling technique – commercially known as 'MetalCopy'. The end product consists largely of steel with a low melting point alloy infiltrant material.

The MetalCopy process involves the following steps:

1. A primary master of the tool is created, typically by an accurate rapid prototyping system
2. A silicone negative is cast from the master
3. The silicone negative is used to produce a 'green' part comprising a mixture of steel powder and binder
4. The green part is sintered and the pores between the metal powder grains are filled by a low melting point alloy metal.

It is possible to utilise these products as tooling inserts for manufacturing processes. Depending on geometrical complexity, the technique may provide time and cost advantages as compared to traditional tool be further developed, the tooling may be tailored to its purpose with respect to material properties, due to the opportunities presented by its powder mixture nature.

Weaknesses revealed

The work began with a case study that revealed several weaknesses of the MetalCopy process to the application for high pressure diecasting. The particular characteristics of the flaws were examined using differing examination techniques.

The test piece used was the 'dyson' geometry (fig. 1). The tooling design produced four parts simultaneously and consisted of five separate inserts, one of these being produced by the MetalCopy process and assembled in the tool along with conventional steel inserts. The tool half concerned and the gating arrangement is seen in fig. 2.

The accuracy of the MetalCopy insert was compared with the .stl file (the form of CAD data used to manufacture the master) supplied by Prototal AB by comparing measurements of different features. The surface roughness (Ra) of an area within the casting cavity was measured before and after diecasting. LM24 was used as the casting material.

The tool was used to produce 500 parts, a quantity previously identified by the project partners to represent a 'low volume' production run. The process cycle time taken to produce one part was 25 seconds, utilising the same process parameters used by a complete steel tool. Initial signs of cracking in the MetalCopy insert began after approximately 50 parts.

This propagated from the central boss feature and continued to progress during continued production. These cracks became clearly visible after some 200 parts. As production progressed to the 500th part, this cracking became more extreme and ablative.

Failure analysis tests

Analysis was conducted to establish the characteristics of the MetalCopy's structure that may have lead to the cracking failures experienced in the case study. Sections were taken from the inserts before and after casting to allow magnified optical analysis of the structure and hardness testing at different positions.

The optical analysis also indicated a level of porosity that was present in the MetalCopy inserts as they were received, and also the variation on steel particle size. Optical investigation of the cracks that were created by the high pressure diecasting showed that they propagated along lines of infiltrant material.

The progression of MetalCopy material for diecasting hinges upon improving its resistance to the cracking experienced in the

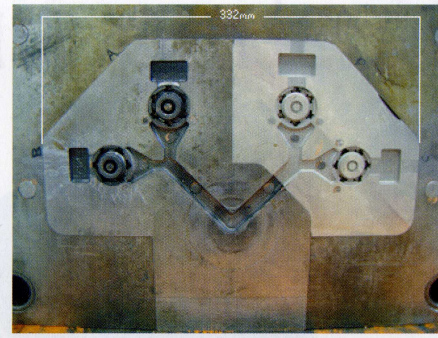

Fig. 2. MetalCopy and steel inserts in the diecasting tool

of the tool material, caused by this heating and cooling, leads to the development of internal stresses that result in cracks appearing in the tooling materials which ultimately lead to its failure.

A thermal fatigue test has been developed by Loughborough University to evaluate tooling materials for high pressure diecasting, the experiment involves a repeated thermal shock treatment by exposing the sample to the temperature conditions that would be experienced in diecasting.

Conclusions

The results show that:

- The MetalCopy insert is undersized in comparison with the supplied .stl file
- The process concerns multiple translation steps
- The comparative accuracy of the translation needs to be examined after each step in order to determine at which point there is a change
- Subsequently, attempts to compensate for the undersizing may be made.

The results have shown that the infiltrant material is a weak point of the process when utilised as high pressure diecasting. It has been shown that cracks propagate along through this material avoiding the steel particles. The inherent porosity that has been demonstrated may also lead to this failure.

It is hoped that the thermal fatigue experiment will allow for a better understanding of the failure mode that will in turn lead to material improvements. The experiment will be utilised to further quantify the processes' suitability for high pressure diecasting tooling and facilitate improvements to powder binder mixture materials.

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