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OPTIMIZATION OF GATING SYSTEM USING MOULD FLOW SOFTWARE: A REVIEW

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ABSTRACT
Casting as a manufacturing process to make complex shapes of metal materials in mass production may experience many different defects such as porosity and incomplete filling. Gating/riser system design is critical to improving casting quality. The objective of this review paper is to optimize gating/riser systems based on CAD and simulation technology with the goal of improving casting quality such as reducing incomplete filling area, decreasing large porosity and increasing yield. Therefore in this paper, an optimization framework is presented based on CAD and simulation technology.Prepare a CAD model of part design and after converting to a casting model, it is the first step to evaluate castability of the casting design. Then the runner and risers are represented parametrically, and CAD models generated by varying parameters can be used in the simulation. After analyzing simulation results, the gating/riser system design is optimized to improve casting quality.

KEY WORDS
Gating system, design optimization, simulation,mold flow,gating system

1. INTRODUCTION

Casting is a manufacturing process for making complex shapes of metal materials in mass production. There are two main consecutive stages, filling process and solidification process, in casting production. In filling process gating system composed of pouring cup, runner, sprue, sprue well and Ingate, is designed to guide liquid metal filling. Riser system is used to compensate shrinkage caused by casting solidification. Casting process design is important for production quality and efficiency.

It is unavoidable that many different defects occur in the casting process, such as porosity and incomplete filling.To improve the casting quality becomes important task. Casting quality is heavily dependent on the success of gating/riser system design, which currently is conducted mainly relied on technicians' experience. Therefore there is a need for the development of a computer-aided casting process design tool with CAD, simulation, and optimization functions to ensure the quality of casting.

The objective this paper is to optimize gating/riser systems based on mold flow software and Rapid Prototyping technology with the goal of improving casting quality such as reducing incomplete filling area, decreasing large porosity and increasing yield.

Therefore in this paper, a mold flow software and rapid prototyping technology based optimization framework is presented. Given RP model of part design and after that it has been converted to casting model, the first objective is to evaluate cast ability of the casting design. Then runner and risers are presented parametrically. By varying each parameter, all models will be obtained. After analyzing simulation results, the original gating/riser system design will be optimized to improve casting quality.

2. METHODS AVAILABLE

Casting is a manufacturing process for making complex shapes. Various methods are available and some are developed by researchers. The analysis of flow during mold filling and the computer-aided design of gating system are discussed (F.J. Bradley & S.Heineman,1993). A gating design methodology based on the control volume hydraulic-based flow model and non-linear optimization is described. The development of a gating design methodology based on a hydraulic fluid flow model and a nonlinear optimization algorithm for automatically sizing gating components subject to specified process and flow parameter constraints has been presented. Details of the mathematical formulation of the flow model have been given and results of flow simulations of water and molten steel have been presented in two-in gate circular cross-section systems. Model predictions were found to be in reasonable agreement with experimental results for most of the cases considered. Discrepancies in model predictions are primarily attributed to uncertainty in loss coefficients. In addition, depending on system geometry, initial transients associated with open channel flow in partially filled runners and ingates may significantly influence the flow distribution through the inmates. Application of the hydraulics based approach to accurate analysis of flow in gating systems requires knowledge of loss coefficients that specifically relate to the flow conditions and types of runner/Ingate geometric configurations encountered in industrial castings. Molten metal experiments are now being planned to calibrate the hydraulic model, extend its application to handle initial transients associated with flow in partially filled sprue, runner, and ingates investigate the influence of system geometry on flow recirculation through ingates during mold.

A new method is developed by Wu et al.[3] Semi-automated parametric design of gating system for die-casting die , the gating system is very critical to die-casting dies, but designing the gating system is an iterative process that can be very time consuming & costly is work is to develop. The aim of this work is to developed automatic generation of the gating system's geometries by applying parametric design. Parametric design deals with variable dimension as control parameters & allows the designers to modify the existing design by changing the parameter values. This paper presents a prototype parametric system for designing the gating system of die-casting. The proposed system is able to reduce the geometry construction time of gating element significantly. It provides guidance to the designer, the system first make trial design of gating system close to the final designer so that time modification & redesign is shortened.

Hu et al.[2] discussed that design & optimization of runner and gating system for the die casting of thin-walled magnesium telecommunication part through numerical simulation. A well-designed runner and gating system is very important to secure good quality die castings through providing a homogenous mould filling pattern. Two types of runner and gating systems were designed and analyzed. A preliminary design with a split gating system led to a swirling filling

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pattern and insufficient central flow, which prematurely closed the edges and left the last filled areas falling into the inner portion of the part. It resulted in a high possibility of air entrapment in the casting and the design was not proper for the part. The design was improved by using a continuous gating system and a bigger size runner. The gate area was increased and the gating speed was slightly reduced. Numerical simulation showed that this new design provided a homogenous mould filling Pattern and the last filled area was located at the upper edge of the part, where overflows and the vents were conveniently attached.

Numerical simulation is a cost-effective tool in the design of the runner and gating systems to visibly analyze the mold filling process. A commercial CAE package (MAGMA soft) was used for numerical analysis. The software is based on the finite difference method (FDM), which couples both the widely used Navier-strokes and Fourier equation. As such, it is therefore believed to have a high accuracy by considering the heat loss during the mould filling stage. AZ91HP alloy and H13 die steel were used for the simulation. Based on the above runner geometry, a split gating design was used. The total number of elements used for simulation was 1.8 million. The total gate area was 22.5 mm^2 (45 mm*0. 5 mm) and the gating speed was set at 100 m/s, which are thought a typical speed for such a thin walled magnesium part.

Optimal Design of gating system by Gradient search Method Carlos Esparza et al. [7]. A numerical optimization technique based on gradient-search is applied to obtain an optimal design of a typical gating system used for the gravity process to produce aluminum parts. This represents a novel application of coupling nonlinear optimization techniques with a foundry process simulator, and it is motivated by the fact that a scientifically guided search for better designs based on techniques that take into account the mathematical structure of the problem is preferred to commonly found trial-and-error approaches. The simulator applies the finite volume method and the VOF algorithm for CFD analysis. The direct gradient optimization algorithm, sequential quadratic programming (SQP), was used to solve both 2D and a 3D gating system design problem using two design variables. The results clearly show the effectiveness of the proposed approach for finding high quality castings when compared with current industry practices.

3. SIMULATION SOFTWARE AVAILABLE

The most popular casting simulation programs available in India include; AutoCast-X, MAGMA, ProCAST, SolidCAST and Mold Flow Software. Some of these are available on hire(monthly, quarterly or annually), which is useful for benchmarking. The programs employ different methods for casting simulation.

1. Finite Difference Method (ex. Solid Cast)

2. Finite Volume Method(ex.MAGMA)

3. Finite Element Method (ex.Procast)

4. Vector Element Method(ex.AutoCAST)

While the underlying physics are same, they differ in term of discretisation (division) of space and time continuum, handling of various material properties (ex. Latent heat), boundary condition (metal-mould interfacial heat transfer coefficient), and the numerical technique employed.

The FDM and FVM use cubic or brick-shaped elements, FEM uses tetragonal or hexagonal elements, and VEM uses a combination of cubic and pyramidal elements. The FEM can model the casting shapes more accurate, but may require manual effort to correctly generate the element mesh, which can sometimes take more time than the computation itself. A separate 3D CAD programs are needed for solid modeling of as-cast parts, the main input for simulation programs. Popular CAD programs include AutoCAST, CATIA, I-DEAS, Pro-Engineer, SolidWorks, SolidEdge, and UG-NX. Most of them offer similar features, and their prices have reduced owing to a large market and fierce competition. The main difference remains in terms of user interface. Since solid modeling can take a lot of time, especially for complex-shape castings, it is best to acquire one which has an intuitive user interface, and familiar to the tool designer working in the foundry. Solid models can also be requested by the OEM customer, or outsourced from a local CAD/CAM agency, reducing the load on the foundry designer.

3.1 Mold Flow Software

It is also known as mold flow design software. In injection moulding, molten plastic is squirted under high pressure into mould. Different flow and cooling rates of plastic can cause flow marks on the surface and wrapping of the finished product, which makes it look untidy.

Designing a new mould is often the most expensive single investment in product development-so it’s better if you find out where problems might happen before you actually make the mold.

That’s why the mould flow computer software comes in. It simulates injection-moulding process, trailing any shape of mould that the designer can imagine. It display colour coded picture of the way molten plastic will flow into the mould and how plastic will shrink or wrap when it cools. Engineers can use this information to design extra cooling channel into the mold and to beef up plastic section that might warp. The toolmaker uses the computer-generated design to make the mould.

Using mould flow, designs for plastic product can be completed without the immense cost of making models or testing and modifying or prototype mould.

4. NEED OF SIMULATION

Casting simulation should be used when it can be economically justified for at least one of the following three reasons;

a) Yield improvement by reducing the volume of feeders and gating channels per casting

b) Quality enhancement by predicating and eliminating internal defects like porosity

c) Rapid development of a new casting by reducing the number of foundry trials

The corresponding cost benefits can be estimated.

Quality improvement reduces the costs associated with producing defective castings, including their transports, and warranty or penalties.

Yield improvement reduces the effective melting cost per casting, and increases the net production capacity of the foundry.

Faster development of casting through virtual trials eliminates the wastage of production resources, and improves the rate of conversion from inquiries to orders, giving foundries an opportunity to select higher value orders.

Not all defects can be accurately simulated. Solidification shrinkage defects(macro, micro and centerline shrinkage) can be predicted fairly accurately. Flow- related defects (cold shuts and holes) can be simulated but may not always match actual observations. Cooling stress related defects(cracks), micro-structure and mechanical properties are difficult to simulate, and extensive calibration experiment may be needed for practical use.

From above it is clear that it is advisable to start with solidification simulation, which requires relatively less inputs, gives fairly reliable results, has a high impact on quality (shrinkage accounts for nearly half of all defects) as well as yield (feeder size optimization), and thus gives a high benefit to cost ratio.

There are at least three other secondary benefits which accrue after using simulation for some time. The corresponding cost benefits are relatively more difficult to estimate, and these reasons are not normally used for justifying setting up a simulation facility.

A Manufacturability improvement by part re-design in consultation with OEM

Method knowledge management by re-using simulation projects

Brand image enhancement by using the simulation facility as a marketing tool.

5. SIMULATION FLOW CHART

There are five distinct stages in casting simulation projects; data gathering, method optimization, and numerical simulation, method optimization, and project conclusion.

1. Data Gathering;- This is the most important stage, since incorrect or incomplete data will lead to inaccurate simulation and wrong conclusions. The problem must be defined first, to ascertain the need and type of simulation. Here we focus on two types of projects; a) quality or yield improvement of an existing casting, and b) rapid development of a new casting.

2. Methods design and modeling;- In this stage, the method design is solid modeled to convert the as-cast part model into a 3D model of the mold containing part cavities as well as feeders, gating channels, cores and feed- aids. If the method design is not available, then the simulation engineer has to first design the above elements based on his experience and foundry practice.

3. Numerical simulation;- This is the main stage in casting simulation, wherein some more critical inputs are required from the user. The first is the correct generation of FEM mesh. The element size must be optimal, and the mesh must be cover the entire model without gaps. The second set of inputs involves factors for various boundary conditions, like the interfacial heat transfer coefficients. There are mainly three types of interfaces; metal-mould, mould-environment, and metal-environment.

4. Method optimization;- This stage involves improving yield. For existing casting, the simulation results are first compared with observed defects to ascertain the cause of defects (undersize feeder, oversize neck, incorrect gate, small cavity gap etc.) Then the method designs modified, solid modeler, imported into the simulation program, and after necessary pre-processing, the casting is simulated again.

5. Project closure;- After finalizing the method design all relevant result need to be properly documented and archived. This includes generating a method report, analysis report images of the major steps and results. A slide presentation or animation can be created for explaining to others. All input and output data, as well as the various reports are stored in a designated folder and backed up. Any discrepancies must be noted in a project file for future references and corrective action (ex. Customization of database).

6. CONCLUSION

In this work we have presented a methodology for obtaining a gating system design of good quality. A proper runner and gating system is very important to secure good quality of die casting through providing a homogenous mould filling pattern. A numerical simulation technique was used for optimization of the runner and gating systems for the hot chamber die casting of a thin-walled magnesium telecommunication part. Two types of runner and gating systems were numerically analyzed.

The preliminary design with a split gating system led to a swirling filling pattern and insufficient central flow, which prematurely closed the edges and left the last filled areas falling into the inner portion of the part. This resulted in a high probability of air entrapment in the casting and the design was not proper for the part.

The preliminary design was improved by using a continuous gating system and a bigger runner size. The gate area was increased and the gating speed was slightly reduced. Numerical simulation showed that this new design provided a homogenous mould filling pattern and the last filled area was located at the upper edge of the part, where overflows and vents were conveniently attached. This new design was considered as an optimized design.

From above work Indian foundries have now understood the importance of casting simulation as an integral part of their operations. The penetration of casting simulation in the country is expected to rapidly rise from its current level of 5-10% through it might take a decade or more to reach nearly full penetration like in Germany and USA. A large number of simulation engineers and consultants will be required to fill the gap.

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