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Quantitative Feeder Design for Metal Castings

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Abstract

Casting simulation packages are used to check a design for its castability. A better starting design should need fewer simulation cycles to arrive at a defect-free component thus cutting computation and manpower costs. Quantitative design of the feeding system is done by an analysis of the solidification pattern of the 3D model of the cast component. A clustering algorithm uses the solidification time/temperature data from the simulation to divide the casting into 3D feeding sections. The sections are created by following hotspots surrounded by areas of decreasing solidification time. Feeders are built by the feeder design module of AutoCAST casting design software. The initial simulation as well as the efficacy of the rigging is tested through the advanced simulation module FLOW+ of AutoCAST X. An industrial case study illustrates the software pipeline in a virtual foundry trial.

Introduction

Computer-aided casting design has made it possible to make trials on the computer before committing the casting to the shopfloor. Most of the casting simulation packages are based on the Finite Difference or Finite Element method for prediction of temperature/solidification time, where computational time grows as the complexity of the cast component increases because of a large number of voxels. Casting solidification simulation tests the design for defects after methoding. A better starting design can reduce the number of simulation cycles and improve cast quality. Feeder design is an important component of methoding. Virtual feed is a software for simulation-based quantitative feeder design [1]. It first divides the casting into feeding sections with a clustering algorithm for volumetric segmentation [2]. However, the algorithm becomes slow and hits the memory limit when the number of voxels during meshing exceeds 3 million. In this new version, the neighbor finding algorithm which requires all the mesh elements to be present in memory, is replaced by a distance-based clustering scheme where the simulation data is divided into small chunks and loaded into memory sequentially. This algorithm is fast and has no memory constraint making it possible for complicated castings with large meshes to be processed in real time.

Methodology

The main steps for simulation-based feeder design are :

1. Solid model of the cast part exported in STL file format from any CAD package.
2. Simulation of solidification of the casting to generate temperature/solidification time profile in the casting.
3. Virtual Feed
   a) Phase I: Data in Step 2 is used to divide the casting into feeding sections using the new algorithm for volumetric segmentation. The sections have decreasing solidification time

values starting from the hotspot towards the outer parts of the section. Volume and exposed surface area of feeding sections is approximately calculated to find the modulus of feeder.

b) Phase II: Optimizing algorithm derives a set of feeder dimensions that give high values of yield and also satisfy the modulus and minimum volume criteria [3,4].

4. Feeders are created in AutoCAST and simulated in FLOW+ (from 3D Foundry Tech) [5]. If the hotspots are not shifted out of the casting, then feeder shape, size and location can be altered or another feeder design can be selected from Step 3b or feedaids can be used [6].

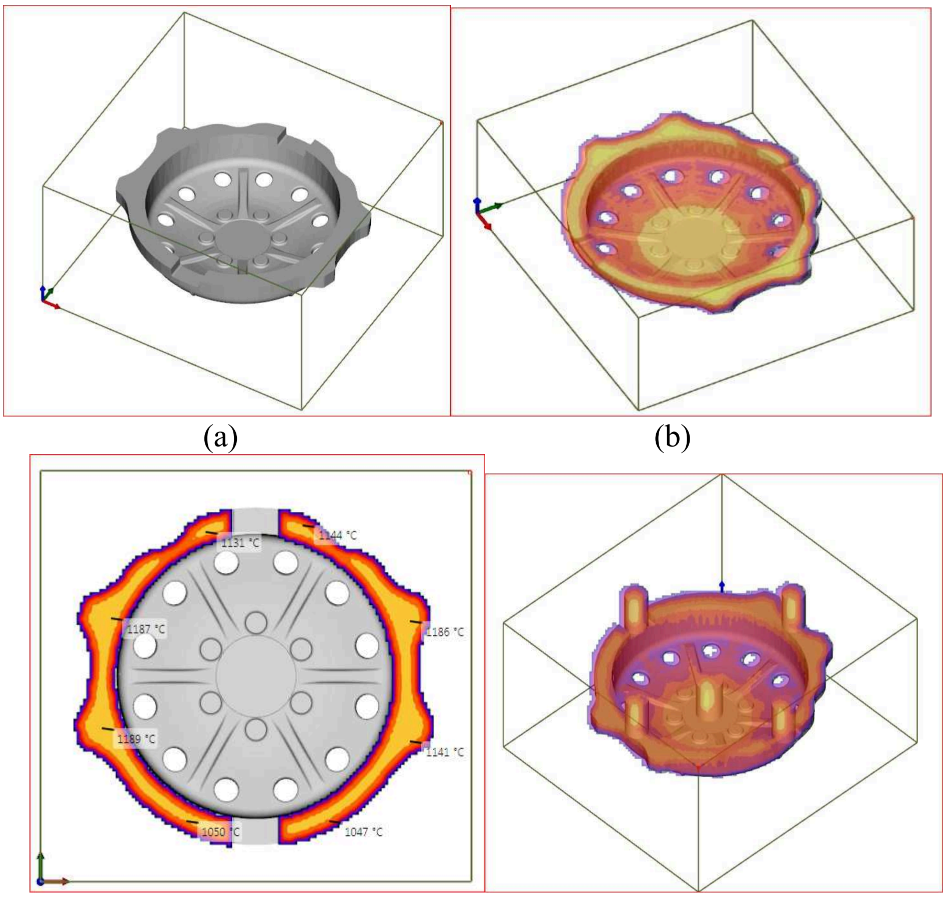
An Industrial Case Study

Solidification Simulation with AutoCAST

The STL model of an industrial cast component is imported in AutoCAST X. The material used for casting this component is Cast Steel (St Low C) and has resin bonded sand as mold material. The values for density, specific heat and thermal conductivity are taken from the database of AutoCAST X. The initial pouring temperature of the melt is taken as 1655^{o} C. Table 1 shows the part dimensions, weight, volume and surface area of the casting component. Figure 1 (a-c) depicts the imported stl file of the casting component without feeders, simulated temperature and solid fraction profile using the advanced flow simulation module FLOW+ of AutoCAST X.

Table 1 : Part data

Part Dimensions	602.31 mm	X 552.61 mm	X 147 mm
Weight 57.41 kg	Surface area	7518.61 cm²	Volume 7863.74 cm³



(a) (b) (c) (d)

Fig. 1 (a) imported model (b) solidification pattern (c) sectional view (d) feeder design in AutoCAST

Analysis of the part in a cross-section through the ear portion of the rim shows a L-junction with a rapid change of thickness, a cause for stress concentration. This may lead to hotspots and porosity shrinkage. Five feeders having a total feeding weight of 7.86 kg were designed using AutoCAST feeder design module (Figure 1d). Exothermic sleeves were added as feedaids to improve the casting yield.

Quantitative Feeder Design

The simulation with AutoCAST discretizes the casting into rectangular cells and generates the solidification profile in the casting. For the present simulation we have taken 3.5 million voxels. The profile characterized by solidification temperature/time at each voxel becomes available. The fast clustering algorithm divides the casting into 3 sections. The hotspots and temperatures are displayed (Figure 2).

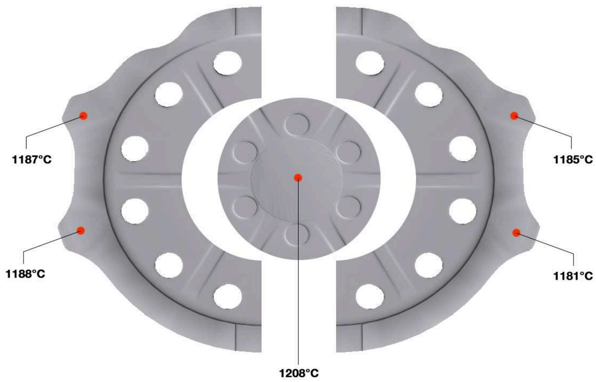
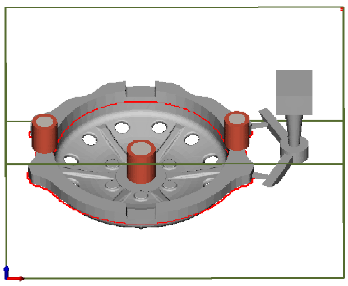


Fig. 2 Top view of feeding sections

Modulus of each section is calculated by estimating the surface area and volume of the sections which is done by summation of cell volumes and calculation of exposed surface areas. Based on these values, required modulus of the feeders are calculated. When the user selects the feeder shape, the optimizing algorithm finds sets of feeder dimensions that maximize the yield while satisfying the volume and modulus criteria. The feeders are created with the methoding module of AutoCAST. The total feeding weight is 4.34 kg with a feeding yield of 92%.



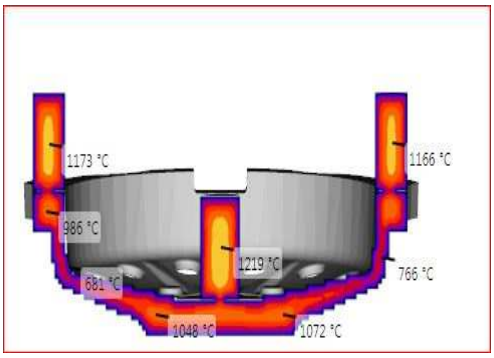


Fig. 3 Solidification pattern with 3 feeders designed with Virtual Feed

Table 2 compares the manual design with Virtual Feed design. The number of feeders is reduced from 5 to 3 using the present methodology which leads to a feeder volume saving of around 45 %. Individual feeder dimensions are available in the methoding report from AutoCAST.

Table 2 : Casting Component Feeder design optimization

	Manual Design	Virtual Feed
Feeders	5	3
Total Volume	1077.11 cm^3	595.07 cm^3
Feeding Yield	87.96 %	92.97 %
Casting Yield	85.15 %	88.67 %
Exothermic Sleeves	10 mm	11 mm
Reduction in feeder volume	44.75 %	

Summary

Quantitative feeder design using a combination of software tools gives the number of feeders, where to place them and the optimum size of feeders. Optimization of feeder volume using the solidification pattern is an attempt to get it right first time. Informed methoding can generate a design which will reduce the lead time and improve cast quality.

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