MAGMA Giessereitechnologie GmbH

Kackertstraße 11

D-52072 Aachen

Germany

Tel.: +49 / 241 / 88 90 1- 0

Fax: +49 / 241 / 88 90 1- 60

Internet: www.magmasoft.com

Email: mail@magmasoft.de

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2 Preface

2.1 Requirements - Why a tutorial?

This tutorial aims at providing a practical introduction into the simulation of iron casting processes. It uses a specific MAGMAiron project to explain typical simulation problems and their solutions.

The MAGMAiron tutorial focusses on simulation aspects and processes specifically related to iron castings and on result interpretation in the postprocessor, whereas the MAGMASOFT® tutorial, which you have also at your disposal, focusses on the basic points of simulation: sensibly structured geometry input, validation of mesh quality, use of the database, definition of simulation parameters, result interpretation.

In order to understand all steps of the case study, you only need the MAGMAiron module of MAGMASOFT®. No functions of other modules are used.

Important requirements for using this tutorial are the participation in a training and the knowledge of how to use the program´s functions. You should also be acquainted with the MAGMASOFT® and MAGMAiron manuals and the MAGMASOFT® Release Notes, as a complete description of the program´s functions is beyond the scope of this tutorial.

2.2 How to use this tutorial

The tutorial´s central case study explains the procedure of casting a brake disc in cast iron with lamellar graphite. Chapter 3, "Process Overview", supplies you with the basics of iron castings and with the most important rules for good simulation practice.

What follows is the explanation of the case study. It contains a complete MAGMAiron project. The project´s first version is described in more detail than the following versions, as it focusses on basic practical MAGMAiron methods and proceedings that are valid for all projects. In the following versions these are required to be known; you should read this chapter (4.3) very carefully.

You are also supplied with a CD-ROM that contains the complete case study project with all versions and files.

This CD enables you to work with the whole case study or with parts of it at your own computer. For example, you can load the brake disc´s geometry and make changes without being forced to input the whole geometry. This tutorials contains many screen pictures, e.g. of the case study´s results. These pictures are always supplied with a short explanation of how to get there. This is going to support you to get a better understanding of the case study´s contents.

2.3 How to use the CD

In order to work through the case study project at your computer, you have to copy the project from the enclosed CD-ROM to your hard disk. The project is called "brakedisc", and its size is about 345 Megabyte. Before installation, please check that there is enough disk space on your hard disk.

2.3.1 Installation under UNIX

1) Insert the enclosed CD-ROM into the CD-ROM drive of your computer.
2) Change into the directory where the CD-ROM is mounted. Most computers running with UNIX automatically mount the CD; there are some platforms, however, where you have to mount the CD manually.
3) Run the installation script "install.sh" or "INSTALL.SH\;1" by entering its filename and pressing the "Return" key.
4) Specify the directory where the project is to be copied and press the "Return" key. All files of the project are now copied into this directory. This may take several minutes.
5) If the message "The installation of the tutorial is finished" appears, all files have been copied successfully.
6) Press again "Return" in order to finish installation.
7) Now you can start MAGMASOFT® and create the project with the 'create project' command.

2.3.2 Installation under Windows NT

1) Insert the enclosed CD-ROM into the CD-ROM drive of your computer.
2) Open the Windows NT explorer and choose the CD-ROM drive.
3) Run the installation script "install.bat": Lead the mouse cursor on its filename and doubleclick with the left mouse button. A new window appears.
4) Specify the directory where the project is to be copied and press the "Return" key. All files of the project are now copied into this directory. This may take several minutes.
5) If the message "The installation of the tutorial is finished" appears, all files have been copied successfully.
6) Press again "Return" in order to finish installation.
7) Now you can start MAGMASOFT® and create the project with the 'create project' command.

3 Process Overview

3.1 The goals of simulation - Overview

Ten golden rules for good simulation

1. The first and most important rule is to make sure that the process being simulated is the same as that being carried out in the foundry. Check very carefully that this is the case. All parameters must be the same. The most important ones are:
   - pouring temperature
   - pouring time
   - mold material
   - core material
   - alloy composition
   - melt treatment quality
2. Define in advance the problem that has to be solved by simulation. Remember that mold filling simulation is very important in all casting processes.
3. Start with a rough test simulation to get an indication that the methoding (rigging) is ok.: Generate a coarse mesh and run a solidification simulation only in order to get some ideas about ingate and feeding behavior. Change the methoding if necessary and perform a rough simulation again. Repeat this if necessary.
4. Continue with a more accurate simulation (more accurate enmeshment, mold filling simulation).
5. Be aware of parameter fluctuation in the foundry (pouring temperature, pouring time, mold density, etc.)
6. Make several simulation runs with different parameter values to see the effects on quality prediction (defect prediction).
7. When comparing simulation results with casting trials be aware of parameter variation.

8. When comparing look at several castings.
9. Use simulation to educate yourself. Get a better understanding of the complex casting process.
10. Store the results you get in a systematic way so that they can be re-used.

3.2 Simulation issues specifically related to iron castings

3.2.1 Introduction

In the following a short introduction is given on how to use simulation to analyze some of the process steps which strongly influence the quality of an iron casting.

Depending on the alloy and quality grade, one of the following casting techniques is normally used:

- **Casting with small feeders.** In this situation the graphite expansion is not large enough to compensate for the total solidification shrinkage of the iron (austenite). Small feeders are used to compensate for this remaining shrinkage to provide a sound casting. In this situation you should define the ingate via the feeders, since this improves process safety and yield.
- **Riserless casting (no feeders).** In this situation the graphit expansion is so large that it can compensate for the shrinkage of the solidifying iron (austenite). In this case it is important that the liquid metal in the gating system can compensate for the liquid shrinkage of the iron casting. This casting method is not used very often.
- **In the third case, the iron alloy has a predominant shrinkage characteristic at the end of the solidification interval.** This leads to a need for feeding during the total solidification process. Feeders have to be used with a modulus larger than that of the casting in order to obtain directional solidification (similar to steel casting layouts). You should define the ingate via the feeders, too, as this again improves process safety and attains higher yield.

3.2.2 Initial solidification simulation

In order to limit the time-consuming simulation calculations you should focus on a mere solidification simulation only. So, before running filling simulations, which take a lot of time:

- use a rough solidification simulation to determine the hot centers in the casting as well as the modulus of these hot centers, and
- use this information to determne the feeder positions and sizes as well as the ingate positions.

3.2.3 Filling simulation for gating designs

Run the filling simulation until the casting is approximately 10% filled, and use the results to design the gating system so it is filled with metal as early as possible during the filling process.

Determine if there is danger that slag will flow with the melt into the mold chamber. Continue the analysis by checking that the flow velocities are not too high to avoid erosion.

3.2.4 Complete filling simulation

Simulate the complete filling. One aim is to get the right temperature distribution as the initial condition for the following solidification simulation. In the third case with the large feeders (Ch. 3.2.1) it is important to check that the temperature distribution in the casting after filling is good (the hot centers have to be in the feeders and not in the casting). It is very important to use these results when analyzing the feeding behavior later on, especially if cold feeders are used.

3.2.5 Detailed solidification and feeding simulation

Now you have to analyze several aspects:

- Is the casting sound? What does the feeding criterion and the thermal modulus ('FEEDMOD') show?

- Are the positions of the feeders correct? Use the feeding criterion or the solidification time to see if the feeders are placed at the shortest distance to the hot centers in the casting.
- Are the feeders too large or too small?
- Is there a need to use more feeders?

3.2.6 Simulation of solid state transformation

First of all, check that the metallurgical settings are correct. Always check to see that the size of the simulated eutectic cells and nodule counts match those in the foundry. This is a need because the overall casting procedures vary from foundry to foundry. It is not necessary to carry out this check for every new project, but every time the melting practice is changed (raw materials, alloy elements, melt treatment, inoculation, etc.), it should be done.

It is good simulation practice to do this check regularly since it can be seen as a kind of quality check that the prescribed melt treatment procedures are followed in the foundry. So make sure that you simulate what is really done in the foundry, including the data for the sand and core materials in use.

4 Case Study - Brake Disc

4.1 Introduction

In this case study the casting of a brake disc is being simulated that is made of lamellar iron and is being poured using the Disamatic casting technology (vertical parting plane of the mold). You find the project on the CD; its name is "brakedisc".

4.1.1 Demands on casting and goals of simulation

The following table gives you a concise overview of which quality criteria have to be met by a brakedisc and what has to be done to achieve these when setting up the simulation:

Important demands on casting	Goals of simulation
No porosity	• Directional solidification into the feeder • Temperature pattern after mold filling is to help placing the feeder
Smooth mold filling	• Gating system may not entrap air • No splashing • No high velocities
Disa process	• Overall size of mold 225 x 600 x 480 mm (DISA machine MK 5A 2013) must be considered during layout of the casting system
High productivity	• Casting in Disa mold

4.1.2 The versions of the project

In the following you are given a short outline about the project´s versions and how they are structured. The project consists of three versions that are set up sequentially:

- The **first version**, 'version_0', already contains the complete geometry including feeders. Solidification and mold filling are calculated. The main focus of this version is to reach a sound mold filling, to get a good feeding effectivity and to find out if there is directional solidification towards the feeders. If this is not the case, isolated areas of remaining melt may occur that can cause porosity (heat centers). There are indeed two hot spots (Chapter 4.3.5).
- In the **second version**, 'version_1', the feeders are made larger. One hot spot is removed now. The other is smaller now, but still exists. Another problem occurs, as the melt is splashing now.
- In the **third version**, 'version_2', the position of the ingate and the geometry of the feeders is changed. Now the heat centers lie within the feeders. Feeding as well as the direction of solidification are now optimized.

Please refer also to the following flow chart.

! **The 'protocol listing' entry of the MAGMASOFT® 'info' menu supplies you with a concise overview of the most important parameters and figures of the whole simulation process, including:**

- **project data**
- **material and heat transfer definitions data**
- **mesh parameters**
- **active options**
- **result file tables**
- **filling and solidification simulation definitions data**

4.2 Flow Chart