Computer assignment MH2252

You have been assigned to design a casting system for a dumbbell according to the geometry file available on canvas. This step-by-step guide has been written to guide you through this process with some points for reflection along the way.

Start by opening Magma by opening the **start menu** and type "**magma**", thereafter **press enter** and Magma should open.

Magma is a software used widely within the foundry industry to design casting systems and troubleshoot casting faults.

Preparations

Do some quick calculations to get an idea of the size of the object that will be cast. Calculate the following:

1. The volume of each cylindrical part of the dumbbell.
2. The surface area of the entire dumbbell.

Starting a project

Create a project by going to the **file menu → new project**, all cases in Magma are stored as projects and each project is divided in versions which can be used to try different settings for a casting system, such as alternate materials, different gating systems or feeder sizes.

Hint: avoid spaces and non-english alphabetic characters in the project name (dash '-' and underscore '_' are OK to use).

Use the default settings for a **sand mould** and **aluminium** as material selection.

To the left there is a bar with icons representing the available perspectives of Magma (*Project, Geometry, Mesh, Definition, Simulation and Results; Optimization and Assessment* will not be used in this lab) they can be thought of as the steps to go through for a simulation. The first perspective that is opened by default for a new project is the *geometry perspective*, here the geometry for the cast product itself is defined together with the gating and feeder system as well as the sand mould.

Geometry definition

To avoid the hassle of drawing up the geometry, simply import the CAD file available on canvas named "dumbbell_v1.stl" by going to the **file menu→import CAD** and select the file “dumbbell.stl” in the directory where it’s saved. Accept to use the global coordinate system. After importing the geometry you should see something similar to Figure 1.

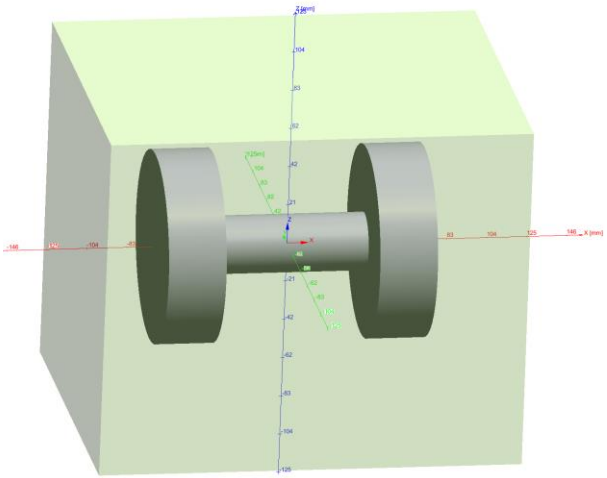

Figure 1. The casting geometry of a dumbbell.

To get an initial idea of the problems that will be faced with this geometry we will do a thermal solidification simulation without any fluid mechanics involved. Before we start defining conditions, we need to define the sand mould that will transport the heat away from the cast component. This is done by the **create menu→3D Volume** and selecting the **automatic mold** option. This will automatically fill up a flask with the size of the component plus an extra 40 mm in all directions, **press OK**.

Now it is time to select which materials are to be used for what purpose. Make sure the sand mould is located at the top of the *geometry tree;* the order in which they are represented here will overwrite the geometry above. Thus, we want the casting shape to overwrite the sand for just this reason.

This step is done automatically. Below the *geometry tree* there is a *material list.* Check that the mould geometry has the material sand mould; if not make it so by dragging the geometry shape in the *geometry tree* to the sand mould property in the *materials list*. Check the same for the cast geometry and make it a casting material.

Right click on “dumbbell_v1” → “Booleans” → “Booleans mode” → “Manual Booleans”

After all geometry settings are done, press the **Update Booleans** button under the **create menu**.

Meshing

Go to the mesh perspective by **left clicking** the **mesh perspective** (third from the top) on the left side bar. Create a mesh with 50 000 elements and press the **generate** button. We will come back to estimating the mesh quality later. Write down the number of cells and number of cavity cells for later use, before closing the dialog window.

Defining conditions

It is now time to define what materials are used for each property. Different property groups can be created to use more than one material for each property. However, we can be satisfied by using one material for each property at the moment.

Go to the **definition perspective** and select materials under the materials definitions category by double clicking the cell under the "Database/Filename" column in the definition navigator tab. Here, choose the *AlSi7Mg-sand* for the casting and *green sand* for the mould sand.

By right clicking on the **initial temperature** column heading there is an option to add columns and an option to add the liquidus temperature to the table. Edit the initial temperature to be 50 °C above the liquidus temperature.

Setting up results

To setup the results go to **result definitions** in the definitions navigator tab. All possible results are not automatically saved, the user has to define what results are interesting for each case and how often it should be saved. For this first simulation we are only interested in the temperature and solidification time. Edit the result conditions **percent solidified** by double clicking the "% from 0.0 to 100.0 % every 2 %", change the step to every 1.0 %.

Starting simulation

Go to the simulation perspective by **left clicking** the **simulation icon** in the perspective toolbar. Now, press the button labelled **start job**. Accept the default in any pop-up dialogue.

Analysing results

Go to the results perspective by **left clicking** the **results icon** in the perspective toolbar. Now, in the result navigation tree look for **"Solidification & Cooling" → "Porosity"** at the time where 100% is solidified. Compare it with the Chvorinov's Rule. Go back to the conditions perspective in order to look up the necessary materials properties for the formula. What are the assumptions for Chvorinov's Rule to apply?

To avoid solidification shrinkage in the cast component a feeder is used. To dimension the feeder an estimate for the solidification shrinkage must be calculated. Do this by taking the difference between the density for the liquid metal at the liquidus point and the solid metal at the solidus point. Now divide this difference by the density for the solid. This is the same as the volume ratio change during the solidification.

Add a feeder

Start by calculating the size of the feeder using Chvorinov's Rule, make sure to account for the centreline feeding resistance.
Now start a new version of this project by going to the *project perspective* and right clicking on the current version and select the option **new version**. Add the description "with feeder" before **clicking finish**.

Define a new local coordinate system under the **create menu → local coordinate system** when the dialog is open, simply left click on the surface that you want to set the origin for the new coordinate system; this will be the reference point for the feeder.

Now and add a feeder to the casting system with the appropriate volume that you have estimated. Add the feeder by importing a dataset through the **file menu → import geometry dataset** and selecting a *side_dome_bottom* feeder, it should look similar as in Figure 2.

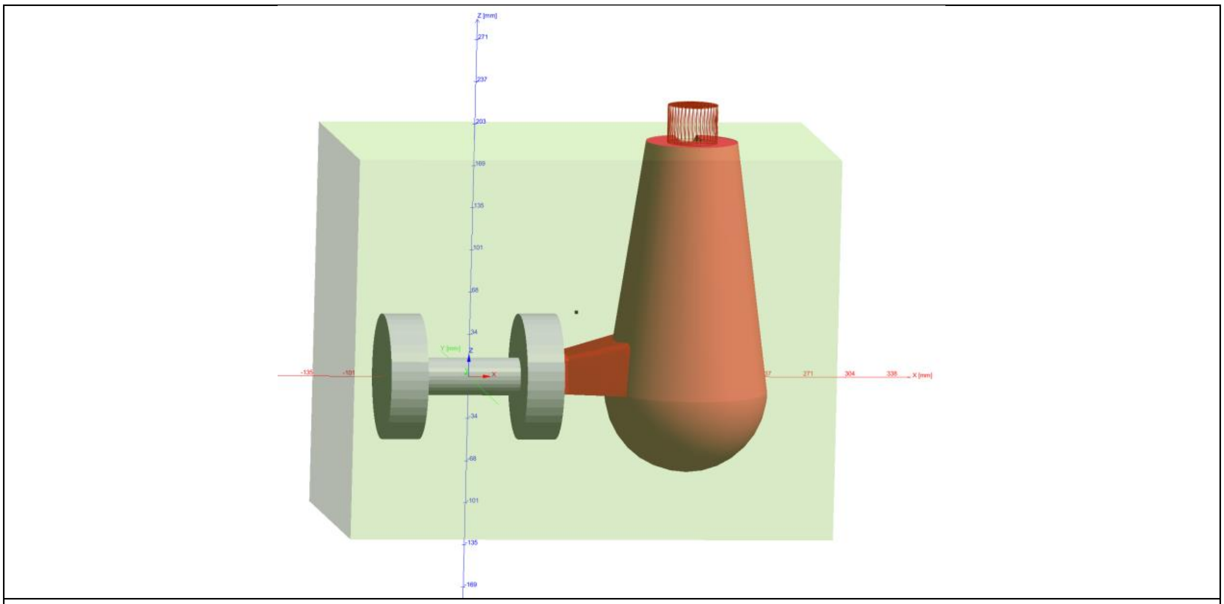

Figure 2. Casting with added feeder.

The sand mould must be redefined, this can be done by double clicking on the *automatic_mold_001* in the geometry tree and generate a new mould.

The pouring of the metal can be defined at the top of the feeder when working in the **geometry perspective**. Define a circular inlet on the top surface by the **create menu → Boundary** and selecting the *circular inlet* option.

Before leaving the geometry perspective choose the option *Update Booleans* under the **create menu**.

Start the simulation with the newly added feeder and check the solidification time and the total porosity of the cast component. Was the size of the feeder enough to avoid solidification shrinkage (pipe) in cast component?

The filling simulation is stopped at a condition when the solid fraction is larger than 70 % (this is called Feeding Effectivity in Magma and refers to the fraction of liquid where feeding is no longer possible) this is to represent the high flow resistance for the remaining liquid. When the liquid cannot feed enough metal to the ongoing solidification shrinkage pores will form. To avoid this we need to make certain that the feeding can proceed and that the last solidified part is in the feeder and not in the cast component. By estimating the solidification time on the isolated side cylinder of the dumbbell and comparing it to the isolated centre cylinder by using Chvorinov's Rule we can estimate the last solidified position. Add a cooling plate with the appropriate added heat flux to help the side cylinder to cool and solidify faster.

Add cooling plate

Now add a cooling plate in the geometry perspective, the end result should look similar to Figure 3. Dimension the chill (cooling plate) with an appropriate heat flux and redo the calculation to avoid the porosity inside the cast component. Compare the porosity with and without the cooling plate, was the added heat flux enough to avoid all porosity in the cast component? If not, why?
Hint: the cooling plate can be made as an extrusion from the side cylinder of the dumbbell.

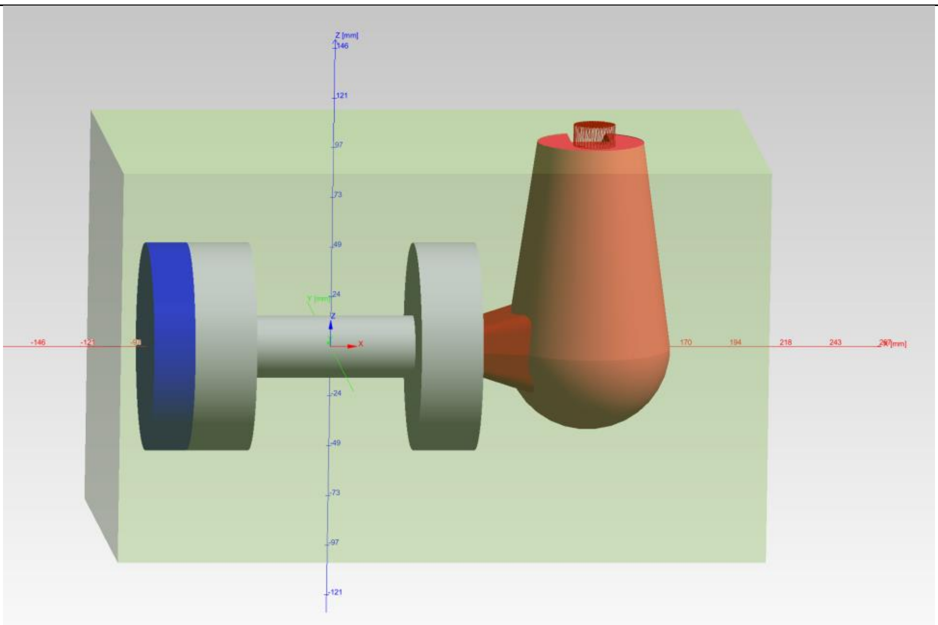

Figure 3. Casting with feeder and chill plate.

Discretisation error estimation

To get a feeling for the discretisation errors due to the chosen mesh a Grid Convergence Index analysis will be done using the available matlab script **GCI.m** available on Canvas. Three simulations with different meshes have to be made. The meshes should be chosen so that a refinement factor of at least 1.3 is satisfied. If the same total volume is chosen for all three meshes, the volume input in the matlab script can be ignored, as these terms will cancel out each other. Finally report the apparent order of the solution together with the approximate relative error, the extrapolated relative error and the fine grid convergence index.

Note: Do this study only for solidification, no filling as this takes too long time.

Report

Summarize the results and calculations in a report according to the template found on Canvas and *upload the finished report on Canvas at latest October 2*.