Network Modeling of Liquid Metal Transport in Solidifying Aluminium Alloys

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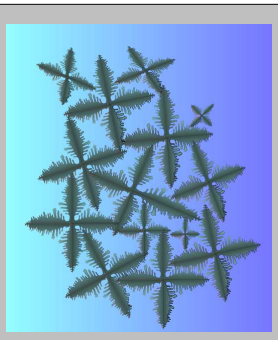
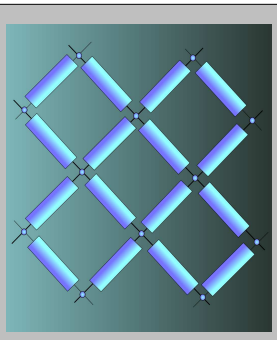
Introduction

During solidification of Al–alloys in Direct Chill castings solid nuclei will form and grow out to dendritic crystals. These irregular crystal grains form together with the surrounding melt the mushy zone. It is this region where all the microstructural characteristics of the cast are determined. When solidification proceeds, the grains will impinge on another and form a rigid porous medium at low liquid fractions.



Inpinged grains.



Channel representation of the model simulation.

Objective

The aim of our numerical simulations is to get a better understanding of the interaction of liquid flow and solidification in the mushy zone at low liquid fractions. This might help to predict occurrence of casting defects, e.g. macrosegregation and freckles.

Preferential flow effect, one of the casting defects.

Numerical Model

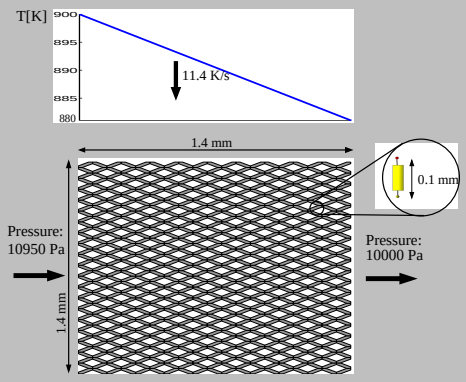
Today phase–field simulations allow to study numerically the growth of only a few grains within a fluid flow. A moderate number of grains is due to the high computational costs nearly impossible. To get insight in the collective behaviour of many grains we therefore investigate the behaviour of rectangular tube networks. The cylindrical tubes represent the liquid conducts of the mushy zone.

As expected, upon solidification the numerical model simulation shows that the liquid fluid flow becomes hampered when the tube network is cooled down. This means that the permeability decreases. Using Darcy law we get permeabilities which quantitatively agree with measurements.

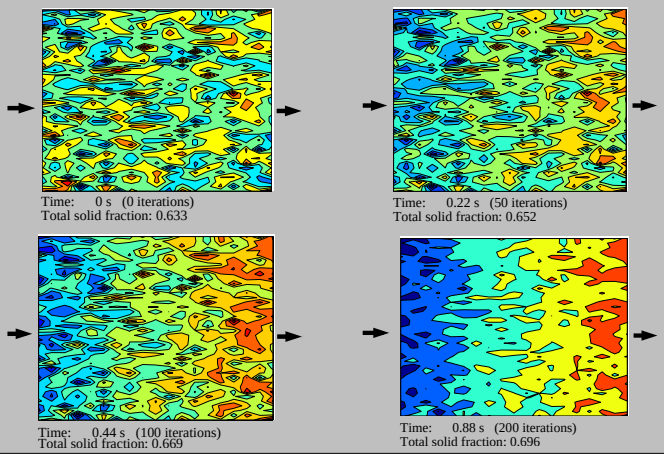
The emergence of certain spatial correlations such as formation of freckles or preferential channels was not observed. We therefore investigate an extended model which allows for convection–induced growth phenomena.

The fi gure of the preferential flow effect is from J.W.K. van Boggelen, *Permeability of the Mushy Zone of Aluminium Alloys*, Master Thesis, Delft University of Technology, 2002.

An example of a simulation:



Solid volume fraction: (blue=high, red=low)



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