Cooperation within MEBSP on the Subject of Air Gap Formation During a Casting Process

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Some work has been done over the years to achieve understanding of the mechanisms behind air gap formation in casting processes. Experimental work has been done as well as work within the subject field of numerical modeling of air gap formation during solidification. It is, however, quite rare to find comparisons between experimental measurements and simulation results with commercial codes.

There are a number of different commercial codes available on the market useful for example for qualitative identifications of various problem areas in complex casting geometries. But to get reliable quantitative predictions of the growth of an air gap in a casting process there still remains a lot of development and research to be done.

To be able to quantitatively check the results from a simulation it is necessary to have measured data from an experimental procedure that is simple to model in a program. Within the MEBSP subgroup IV members such experiments are made. There are also four different simulation programs available within the group for calculating solidification as well as thermal stresses and strains during a casting process. The aim of the work of MEBSP subgroup IV within this area is to get a better understanding of the models implemented in the codes and see how well the existing models fit to experimental data. It is also of interest to see if the different models give quantitatively the same results and whether any of the four programs have special suitability for certain purposes.

At the Division of Casting of Metals at the Royal Institute of Technology, KTH, a lot of experiment based research is taking place within the subject field of casting. In the area of air gap formation the work is focused on the behavior and properties of a solidifying metal during solidification and the influence these have on the shrinkage behavior, the solidification process and the air gap formation.

In order to study the solidification process coupled with the air gap formation an experimental set-up has been constructed. It consists of a cylindrical mould made from low alloy steel which is insulated at the bottom and the top so that solidification occurs axisymmetric. In the center of the cylinder a cylindrical core is placed, made from quartz glass filled with oil bound sand. Figure 1 shows a schematic drawing of the set-up.

The radial temperature distribution is recorded during cooling and solidification via thermocouples placed in the mould and the casting. Simultaneously, the movements of the mould walls and the outer surface of the casting are measured with linear variable differential transducers (LVDT). Figure 2 and 3 show an example of results from this kind of experiments. These particular curves are taken from experi-

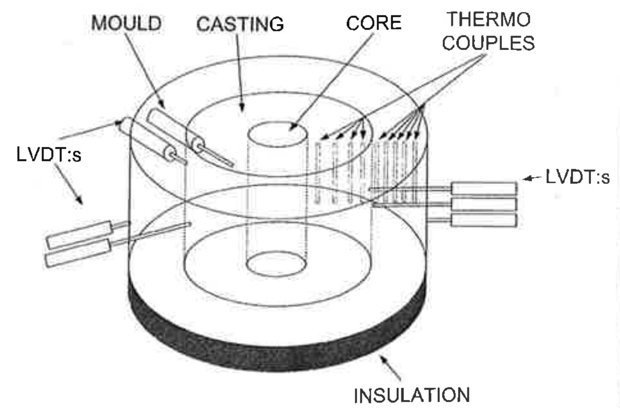

Fig. 1. Experimental set-up for air gap studies [1].

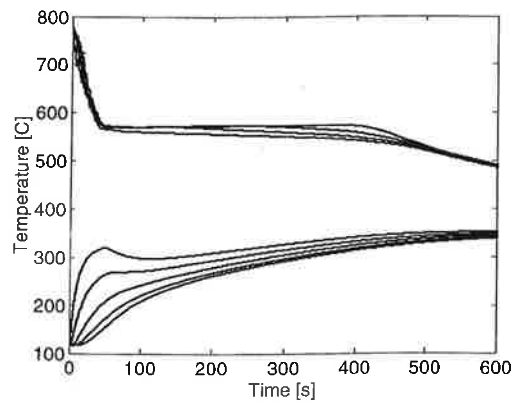

Fig. 2. Measured temperatures in mould and casting [2].

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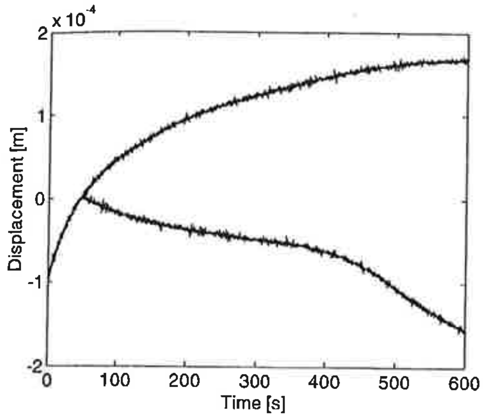

Fig. 3. Measured displacements of inner mould wall (upper curve) and casting (lower curve).

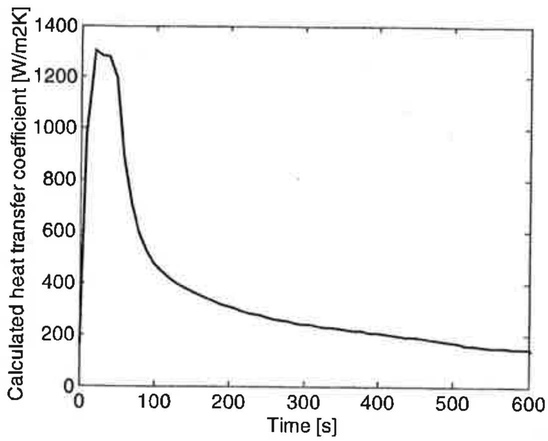

Fig. 4. Heat transfer coefficient calculated from measured temperatures [2].

ments made with Al-13 % Si as cast alloy. Figure 2 shows the temperature measurements and Figure 3 shows the radial displacements. Outward movements are considered positive. Initially the mould expands and the cast metal follows the expansion. But after some time the metal shell is able to withhold its shape and starts to contract while the mould continues to expand. The result is a growing air gap.

From the recorded temperature distribution a heat transfer coefficient can be deduced as a function of time. For this example such a curve is shown in Figure 4. The heat transfer coefficient has a high value before an air gap has started to form. This value is determined by the contact resistance from mould roughness, coating, possible oxide layer of the melt etc. When an air gap starts to form the heat transfer coefficient reduces and is controlled by the conduction over the gap in the case of aluminium base alloys. More information about the experimental method is available in earlier work.[1–2]

The experimental data could be used for simulation in any simulation program available. Within MEBSP subgroup IV there are four programs available for dealing with these kinds of problems. At the Foundry Institute at RWTH in Aachen, MAGMA and CASTS-SPAN3D are used. MAGMA is a commercial code whilst CASTS-SPAN3D is an in-house code developed at the Institute.[3–4] The Technical Research Center of Finland, VTT in Espoo uses PROCAST which is a commercial simulation program for casting.[5–6] The Center for Material Processing, Ecole de Mines de Paris, Cemef in Sophia-Antipolis uses THERCAST which is a commercial code developed by Cemef in cooperation with Transvalor.[7]

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[1] J. Kron, H. Fredriksson, presented at ASM Materials Solutions Conference and Exposition, Columbus OH, October 2002.

[2] J. Kron, T. Antonsson, H. Fredriksson, *Int. J. Cast Met. Res.* **2002**, *14*, 275.

[3] see http://www.magmasoft.com

[4] CASTS is an in-house code developed at the Foundry-Institute of the Technical University Aachen together with ACCESS Material Sciences e.V., Aachen. SPAN3D is a stress module developed at the Foundry-Institute for uncoupled stress simulation based on the results of CASTS. Both, CASTS and SPAN3D are not for sale.

[5] see http://www.calcom.ch/Products/Procast.html

[6] see http://www.ues-software.com/subhtm/products/Procast.html

[7] THERCAST presentation on www.transvalor.com/ and www.scconsultants.com/