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Numerical simulation of porosity for Al based alloys

Marek Brůna*, Dana Bolibruchová, Richard Pastirčák

University of Žilina, department of Technological Engineering, Univerzitná 8215/1, 010 26 Žilina, Slovakia

Abstract

The final integrity of a casting is greatly influenced by the presence of porosity. Progressive way to predict presence of porosity is the use of modern computer simulation programs. The main aim of performed experiments is to verify possibilities of this promising method of porosity prediction. A calculation of advanced porosity prediction was performed for an aluminium alloys by advanced porosity module included in ProCAST software. This calculation takes into account all basic phenomena, which are at the origin of micro and macro porosity. For experiment purposes was used mold with specific shape – Sanduhrprobe. Materials used in experiments were not loaded from software database, because results could be distorted by deviations from particular material we used. To achieve precise results, we used thermal analysis to get accurate data about used alloys. Important solidification events, which affects porosity formation, such as recoalescence and nucleation undercooling temperature, coherence point and rigidity point have been determined from cooling curves and its first derivate. These data were then included to the database of simulation software and used in simulation process.

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Keywords: Thermal analysis; aluminium alloys; porosity;

1. Introduction

Most frequently occurring defects during casting of Al alloys are those associated with porosity. In this type of alloys, porosity forms during solidification, in the mushy zone, where two mechanisms take place: Hydrogen segregation/precipitation (hydrogen porosity) and insufficient interdendritic feeding (micro-shrinkage). This resistance causes a local pressure drop of the liquid by Darcy's law [1]. The precision in the prediction of porosity depends on the adequate use of physical and thermal properties of the alloy and mold under study, as well as the initial and boundary conditions that define the system. Submitted work presents a case of study where the data

* Corresponding author.
E-mail address: marek.bruna@fstroj.uniza.sk

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utilized in the simulation programs will be optimized to make it representative for a resin based mold gravity casting process, in order to be able predict amount and character of porosity. The simulation of the mold temperature distribution and metal cooling curves will be analysed and compared with experimental values as well as porosity in real castings.

2. Experiment

2.1. Used alloy and its properties

The AlSi7Cu0.5Mg alloy was used in the following studies. Chemical composition is listed in table 1. Company NEMAK, which helped us with experiments, uses mentioned alloy in their production and they have exact composition of every batch, so it was possible for us to make identical alloy for simulation purposes.

Table 1. Chemical composition of AlSi7Mg0.5Mg

Al	Si	Fe	Cu	Mn	Mg	Zn	Sr	Ti	Ca
91.54	7.18	0.15	0.49	0.061	0.375	0.01	0.0106	0.17	0.0006

2.2. Mold material, design and properties

As mold material was selected resin based sand mold. Mold material was a compound of silica sand "SH 32" (D50 = 0.38 mm) with resin „Avenol NB 700" (1,5 % wt. of silica sand) and last substance was hardener „katalysator 4040" (25 % wt. of resin). Design of mold and casting is based on German porosity test called sanduhrprobe (fig. 1a). Shape of casting is chosen with respect to porosity formation. Main aim was to find the right shape of mold cavity, so various types of porosity can occur during solidification. Top part of casting is optimized for creation of pipe shrinkage (not analysed in this work). Bottom part connected with top part through narrowed area (which will solidifies first and additional feeding will not be possible) is ideal for formation of internal micro and macroporosity in the bottom part.

2.3. Thermal analysis

In experimental work, thermal analysis was executed mainly to obtain useful data for simulation software. As will be told below, one of the main advantage of used software is the possibility to consider presence of mushy zone in association with the porosity formation. Several metallurgical parameters are required in order to properly characterize the mushy zone. The permeability, which depends on the number and tortuosity of flow channels, as well as precise information on the interdendritic liquid such as its composition, viscosity, density, etc. are necessary. The dendrite coherency and dendrite rigidity also affect the characteristics of the mushy zone. These parameters vary with temperature and time, as well as from one location to another [2]. In text, graphs and figures below are shown preparation techniques for measurements and few major parameters obtained in thermal analysis. On figure 1 is shown placement of five thermocouples for thermal analysis.