ARCHIVES of FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 8
Issue 1/2008

163 – 168

31/1

# Simulation of mould filling process for composite skeleton castings

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Received 09.07.2007; accepted in revised form 07.08.2007

## Abstract

In this work authors showed selected results of simulation and experimental studies on temperature distribution during solidification of skeleton casting and mould filling process. The aim of conducted simulations was the choice of thermal and geometrical parameters for the needs of designed calculations of the skeleton castings and the estimation of the guidelines for the technology of manufacturing. The subject of numerical simulation was the analysis of ability of filling the channels of core by liquid metal at estability technological parameters.. Below the assumptions and results of the initial simulated calculations are presented. The total number of the nodes in the casting was 1920 and of the connectors was 5280 what gave filling of 100% for the nodes and 99,56% for the connectors in the results of the simulation. Together it resulted as 99,78 % of filling the volume of the casting. The nodes and connectors were filled up to the 30 level of the casting in the simulation. The all connectors were filled up to the 25 level of the casting in the simulation. Starting from the 25 level individual connectors at the side surface of the casting weren't filled up. The connectors weren't supplied by multi-level getting system. The differences of filling the levels are little (maximally 5 per cent).

**Keywords:** Skeleton castings; Simulation; Casting, Solidification

## 1. Introduction

Because of great possibilities for porous materials application in today industry [1÷6] it is advisable to find low-cost methods of its manufacturing.

Skeleton castings are the intermediate of solutions metal materials between the monolithic casting and metallic foam. Skeleton castings should compete with the other ones used [5,6] in the industry of porous materials.

The process of producing the skeleton casting mainly depends on the creation of the core that has designed geometry. The hypothetical process of creating such core was presented in the studies [7,8].

Studied skeleton casting belong to the group of materials with open cells due to their construction [7,9,10]. It also contributes to open possibilities for multi-phase materials manufacturing with non-monolithic spatial structure. [11]. This can be obtained by connecting the skeleton with cell cavities filling material in a composite process. As a filling material different types of materials can be used, for example: other alloys, polymers, or ceramics [12,13].

Based on conducted previous simulation for AlSi11 it was found that metalostatic pressure has the important influence on quality of filling. It worsens due to the fall of pressure at the higher levels of the cast, although the general outline of the cells is seen. Moreover due to the rising height of the cast for the assumed geometrical and thermal system the inaccuracy of predicting filling the mould cavity would increase. The number of filled up nodes and connectors diminished at the higher levels in the real casting [7,13].

It is necessary to conduct the next simulations with changeable geometry at different initial casting conditions in order to get proper filling the mould cavity.

In order to increase castability pouring temperature was rise and multi-level one was used that might lead to diminishing the grade of dividing the stream of liquid metal into the units. It might also bring filling the mould of skeleton casting closer to the traditional casting.[13].

## 2. Numerical simulation

The simulation was conducted with use 'NovaFlow & Solid' software [14]. AlSi11 alloy was used for simulation tests. Its properties [13]:

$$\lambda = 130 \ W/m \cdot K$$
$$c = 1190 \ J/kg \cdot K$$
$$\rho = 2500 \ kg/m^3$$

and crystallization heat:

$$L = 389 \ kJ/kg$$

The chemical composition of AlSi11 alloy was presented in the Table 1.

Table 1.
The chemical composition of AlSi11

| Add | Al | Si | Mg | Mn | Cu | Ni | Zn | Sn |
|---|---|---|---|---|---|---|---|---|
| Composition % | 82,95 | 10,50 | 0,10 | 0,50 | 2,50 | 0,30 | 3,00 | 0,15 |

The typical properties of core and mould sands [7, 11, 13] were established.

The temperature of pouring was 740$^0$C and the temperature of the mould and the ceramic core was set to 180$^0$C.

The basic subject of computer simulation was the analysis of ability of filling the channels of core by liquid metal. Broad use of skeleton castings demands forecasting, by the means of simulation, of filling the mould cavity [13].

The simulation assumptions took into account manufacturing the casting of the multi-level getting system. The shape of the model casting with its core and multi-level getting system was presented in Fig 1.

The level of filling the mould cavity at the consecutive levels of the simulation casting was observed for initially accepted geometrical parameters of the getting system.

## 3. The results of numerical simulation

During simulation effect at mould filling process for the skeleton casting was analyzed.

During pouring moulds distribution of the temperatures was analyzed. In the beginning metal is flowing at the external surfaces of the skeleton casting (Fig 2a). The external surfaces are perpendicularly to first ingate. Metal is flowing to following ingates and flowing down mould inside the core (Fig 2b). Metal is flowing out following ingates and filling mould. First metal is filling the horizontally middle channels of a core (Fig. 2c). Next to metal is flowing at the external surfaces and filling perpendicularly channels of mould (Fig. 2d).

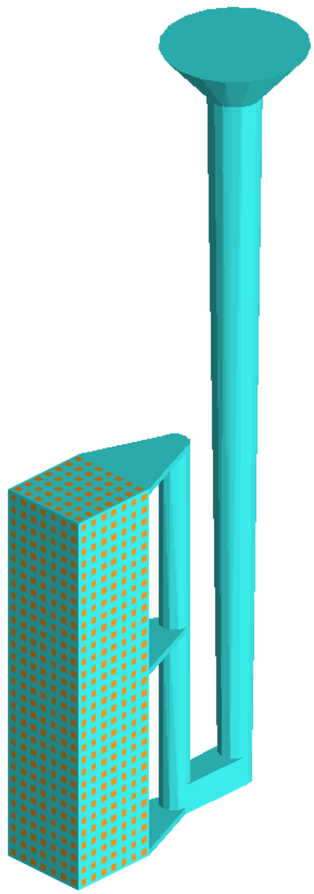

Fig 1. The view of the model cast with its core and multi-level getting system

Presented graphs (Fig. 3) pouring mould show solidification in individually channels of a core (Fig 3a, b). Whole casting is solidification in finish of pouring mould. It is advantageous by reasons of satisfactory mould filling. First solidification is in the lower external part of casting; surfaces aren't connected with double multi-level getting system, next solidification is in the upper middle part of casting (Fig 3c,d).

Liquid alloy, even not flowing through the whole section of the connectors, can fill the nodes that are the places where metal streams meet. Simulation filling of the mould cavity with metal in the areas – adequately of the nodes and connectors, is shown in the Fig. 4 and 5.

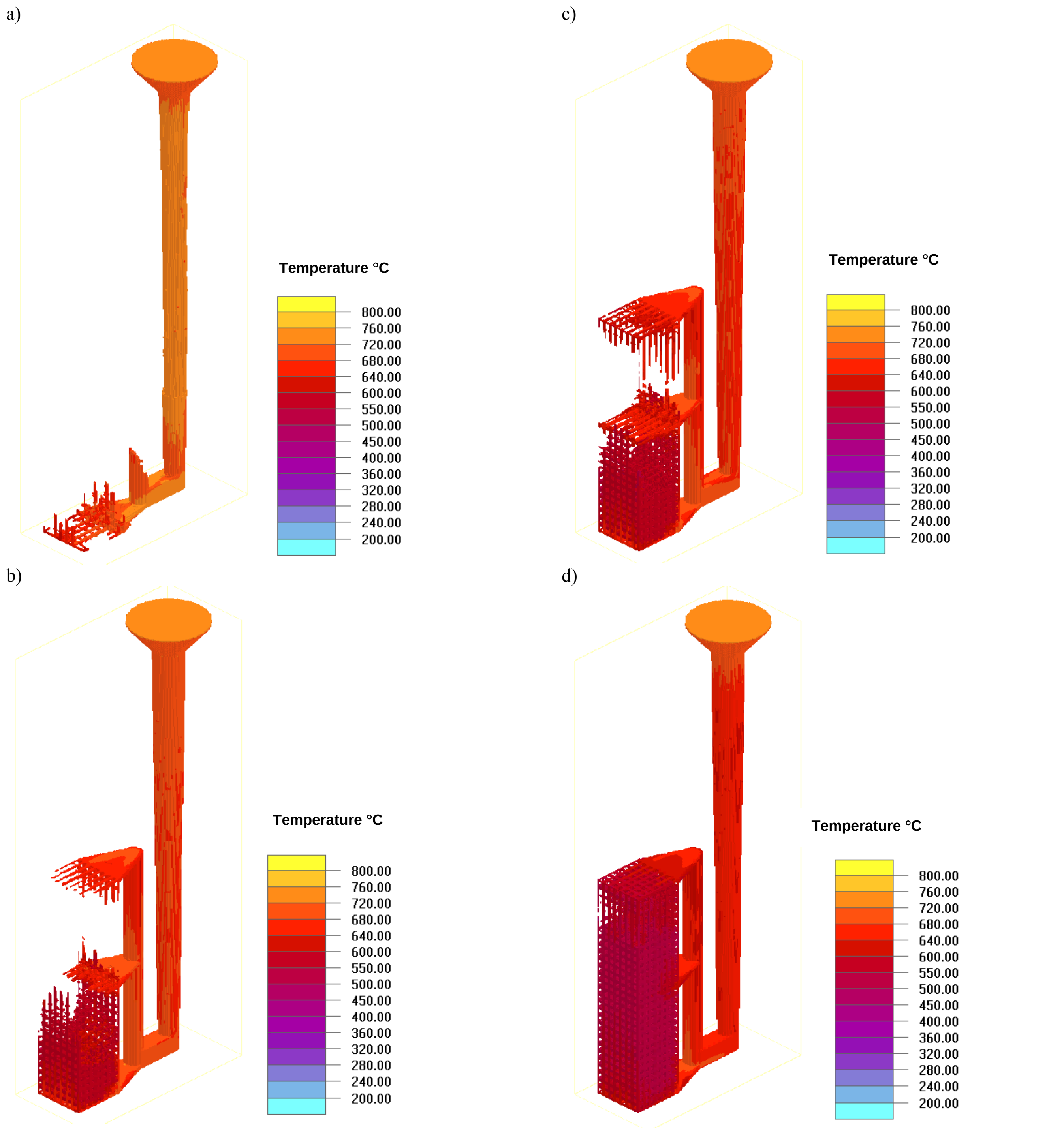


Fig. 2. The results of filling and temperature distribution during casting and cooling the virtual cast. The scale is adequate to the established local temperature of the cast.

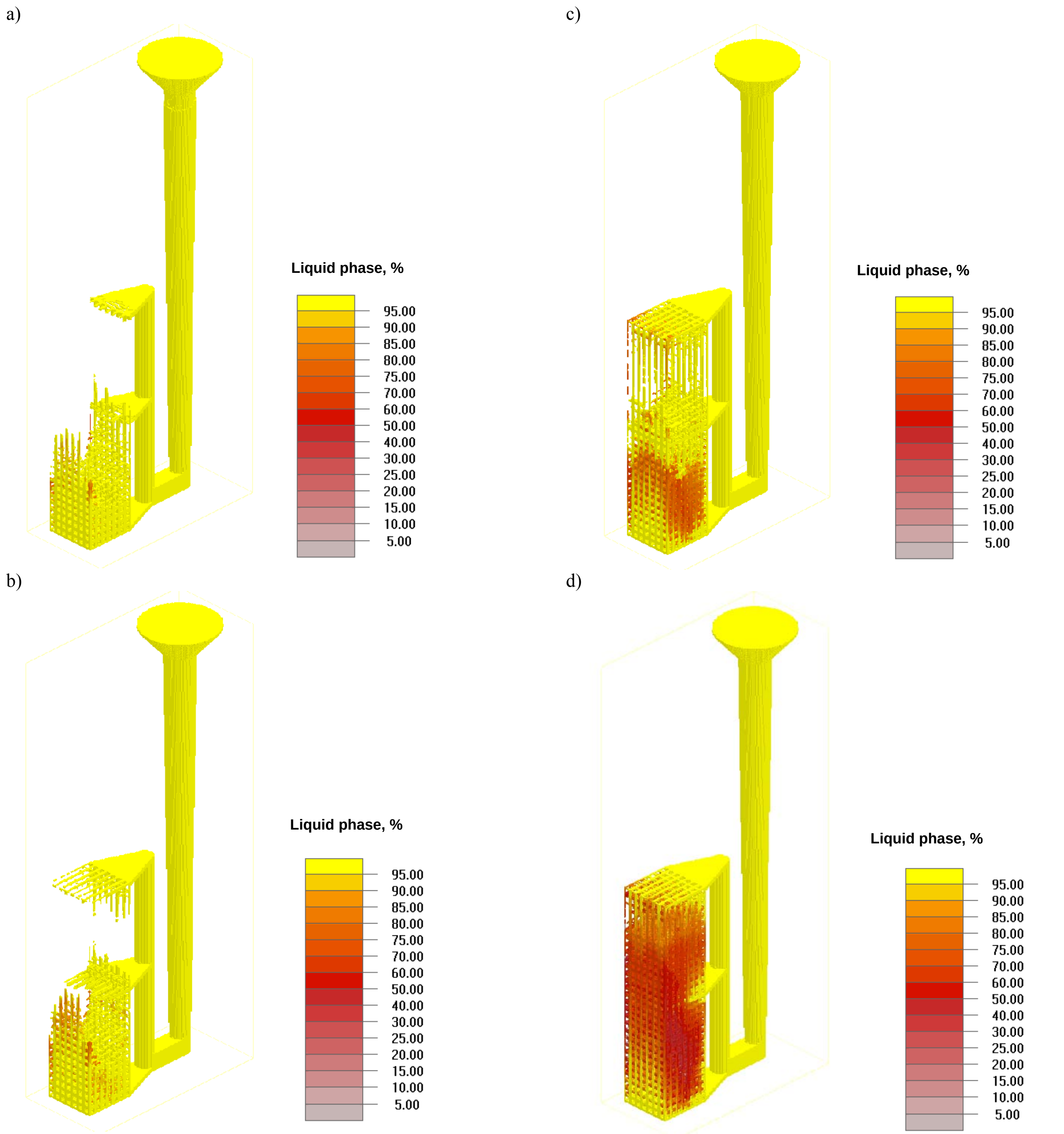


Fig. 3. Liquid phase in different time

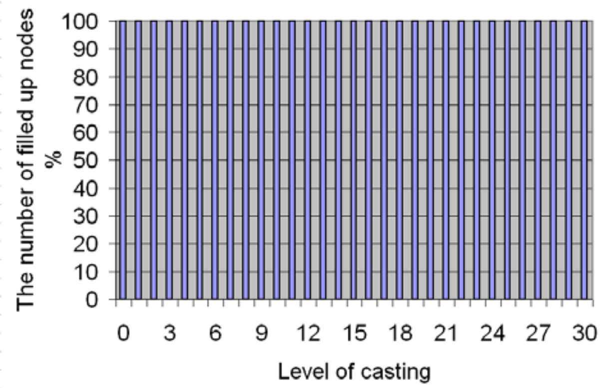


Fig. 4. The number of the filled up nodes at the individual levels of the skeleton casting that has been obtained through the computer simulation.

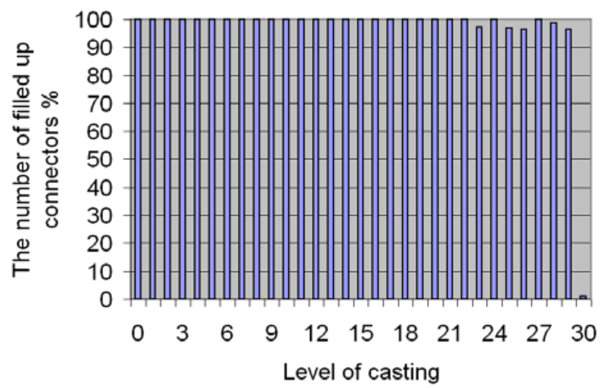


Fig. 5. The number of the filled up connectors of the skeleton casting that has been obtained through the computer simulation

Filling of the nodes and metal connectors at the individual levels of the skeleton casting was analyzed. The total number of the nodes in the casting was 1920 and of the connectors was 5280 what gave filling of 100% for the nodes and 99,56% for the connectors in the results of the simulation. Together it resulted as 99,78 % of filling the volume of the casting. Modulus of solidification of a node is greater than that of a connector. Filling of the node is technologically easier. The inner nodes can momentary be reinforced by 6 nodes, whereas external be reinforced by 4 nodes. The minimum amount of the connectors reaching to the node is 3 (corner nodes). The connector links only two nodes. That is why the efficiency of filling the nodes is greater than of the connectors what was confirmed by the results of the simulation.

The nodes and connectors were filled up to the 30 level of the casting in the simulation. The all connectors were filled up to the 25 level of the casting in the simulation. Starting from the 25 level individual connectors at the side surface of the casting weren't filled up. The connectors weren't supplied by multi-level getting system. The differences of filling the levels are little (maximally 5 per cent). 'Not filled up' connectors with the concave front have not been found in the simulation casting. It indicates at good taking gases out from the elementary volumes of the core (pressure of the flowing metal was higher than pressure of gasses expanded with the rise of temperature).

# 4. Conclusion

Based on conducted studies following conclusion were formulated:

1. Simulation at establishes thermal and geometrical parameters was investigated. It was obtained satisfactory filling the channels creating the skeleton shape and prepared in form of a core.
2. In spite of positive mould filling, it is necessary to diversification of section the ingates, in order to evasion "rainy's" filling the channels creating the skeleton shape and prepared in form of a core.
3. Based on conducted simulations it was stated influence technological parameters (besides metalostatic pressure) influence on space filling of mould.
4. Based on obtained results of research it was determined directions of following experimental and simulation studies.
5. It is necessary to estimation of the guidelines for the technology of manufacturing skeleton castings and guidelines for design getting systems. The aim of the investigation is getting whole mould filling.

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