SIMULATION OF FLOW AND SOLIDIFICATION OF ALLUMINUM ALLOY AND FLOW OF GRAPHITE PARTICLES DURING FILLING OF MOULD CAVITY THE COMPOSITE SUSPENSION

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Abstract

The purpose of the work has been the evaluation of flow and solidification of AlMg10 alloy during the fill mould cavity in the spiral fluidity test and simulation of graphite particles movement during the filling of mould cavity the composite suspension on AlMg10 alloy matrix. This evaluation has been performed on the basis of computer simulation of the mould cavity filling and the solidification of the casts using by means of the Nova Flow and Solid program. The AlMg10 alloy has been cast into the oil sand mould. During the simulation changes of temperature have been registered, the solid phase fraction growth has been observed, and the changes of flow rate in the mould channel have been recorded until the flow stop. A series of figures presents the arrangement of the graphite particles during the subsequent flow stages and after the flow stop. This distribution of graphite particles has been compared with the results of particle trajectory calculations obtained from the solution of the flow equation showed in earlier publications.

Keywords: Composite, graphite particle, aluminum alloy, simulation, solidification

1. INTRODUCTION

The phenomena occurring during the flow of metals in the casting moulds are the most important for casting production. Filling of the cavity mould must be such as to preclude the risk of defects of the future casting. Many factors affect the proper filling of the cavity of the mould. These are factors related to the nature of the metal itself such as the alloy's chemical composition, setting points range, specific heat, thermal conductivity, viscosity, or surface tension. The ability to fill the mould cavity is also influenced by factors related to the casting mould such as the shape of the filler system, the thermophysical properties of the moulding material, mould surface quality, and factors related to casting conditions such as the degree of overheating and the time and rate of pouring [1-6]. The complexity of the flow phenomena, combined with heat transfer and solidification phenomena, makes this problem so far unresolved.

The input of ceramic particles into the molten alloy changes most of these factors in particular the metal parameters, and therefore strongly influences filling the mould cavity [7-9]. Ceramic particles primarily cause changes in the viscosity of the flowing liquid, change the thermodynamic properties of the alloy, affect the crystallization process by interacting with the crystallization front or the nucleating. By interacting the particles with the crystallization front, there may be irregular distribution in the volume of the matrix [10-14]. Difference in density of matrix material and reinforcing particles also contributes to the irregular distribution of particles. The placement of the particles generally influences the properties of the composite. The irregular distribution of the reinforcing phase in the composite matrix causes the composite, regardless of the type of reinforcement, to exhibit relatively low mechanical or tribological properties. Therefore, it is very important to learn about particle flow mechanisms and their distribution in the matrix. Knowing the particle distribution in the composite, it is possible to pre-estimate the future properties of metal composites reinforced with ceramic particles.

In recent years, research into the flow of metals and alloys in mould channels using computer simulations has been intensively developed [15-16]. However, the modelling of mould cavity filling processes should be based on experimental data to simulate near real conditions. Knowledge of the set of characteristics the flow of liquid metal in the cavity mould, ie. flow velocity or change of solidification temperature enable verification of computer simulations of these processes.

2. METHODOLOGY OF RESEARCH

Simulation of mould cavity fill and solidification of the casting was performed using the Nova Flow and Solid computer program. The AlMg10 alloy with a wide range of solidification temperatures were selected for model studies. Numerical simulation of the flow of metal during filling of mould cavity made of oil moulding mass was carried out. The spiral cast has a trapezoid cross-section with a base of 9 and 5 mm and a height of 7 mm. The alloy was cast by gravity and the pouring temperature was set at 670 °C. During the simulation of flow and solidification of AlMg10 alloy, metal temperature changes, pressure changes in the mould cavity were recorded. It was observed how the flow rate of the test alloy changed and the change of the solid phase share during the solidification of the test material was observed.
Simulation of the flow of graphite particles was also performed during the filling of the mould cavity of the AlMg10 alloy composite suspension. The model solution included the flow of graphite particles with a particle size of 100 μm and a density of 2000 kg/m^3, in a flowing AlMg10 alloy with a density of 2300 kg/m^3. It was assumed that the composite suspension was cast to the same mould as the AlMg10 alloy of the same temperature.

3. RESULTS OF RESEARCH

Figure 1 shows the temperature field of AlMg10 alloy flowing in the spiral mould channel recorded by the program during the simulation. From the figure it follows that the flow of melt stops when the temperature at the end of the spiral reaches 566 °C, that is, the flow stops before the alloy reaches the equilibrium solidus temperature, which for AlMg10 alloy is 520 °C.

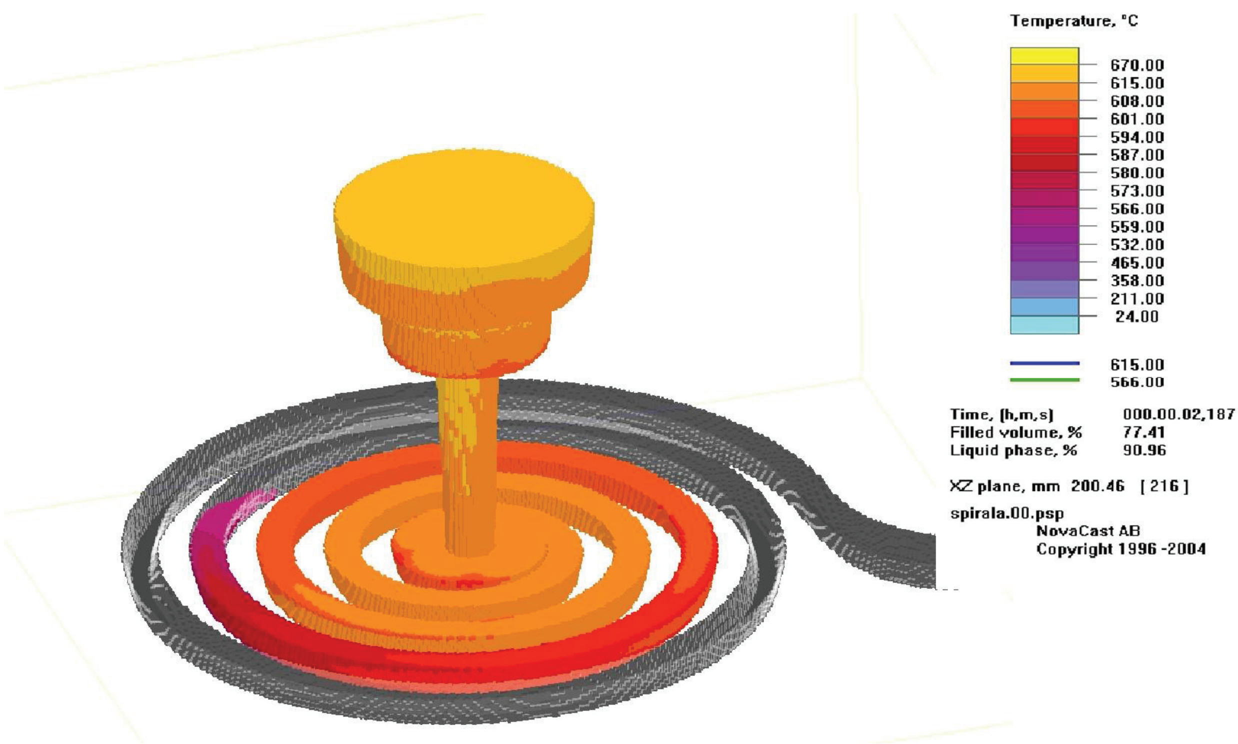

Figure 1 Temperature field of AlMg10 alloy flowing in casting mould

Figure 2 shows the change in the liquid phase share of the spiral cast length after the end of the flow.

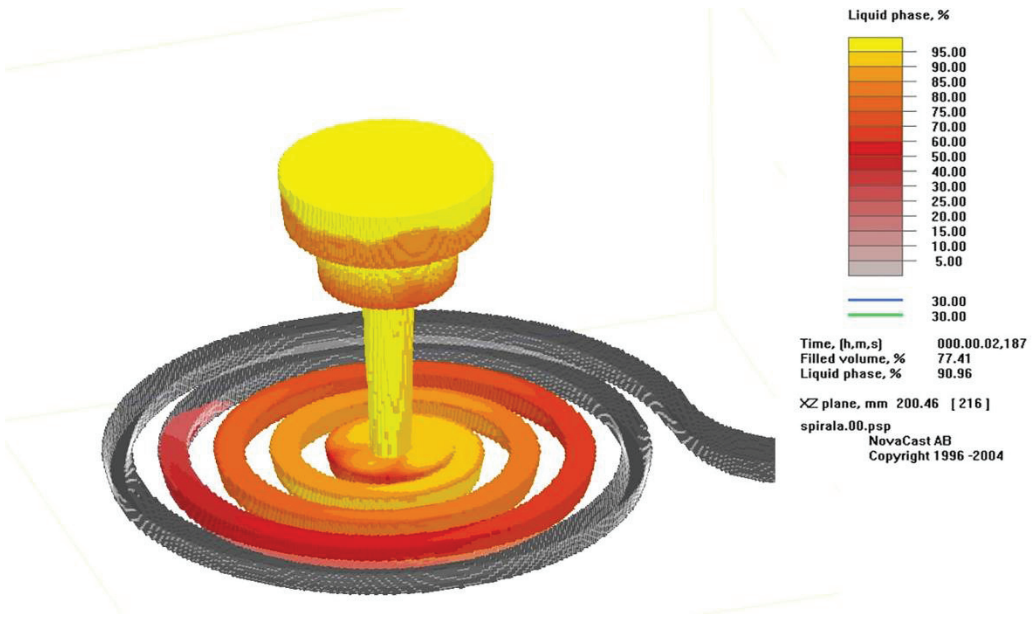

Figure 2 Liquid phase AlMg10 alloy in the casting after the flow

The **Figure 2** shows that after the end of the flow at the end of the spiral is still 25 % of the liquid phase and yet the stop no longer flows. The sprue is 95 % liquid whereas close behind the sprue area is 90 % liquid phase. Of course, the further downstream of the sprue, the share of liquid phase decreases. The velocity fields in the subsequent stages of the melt flow in the mould channel are shown in **Figures 3-5**.

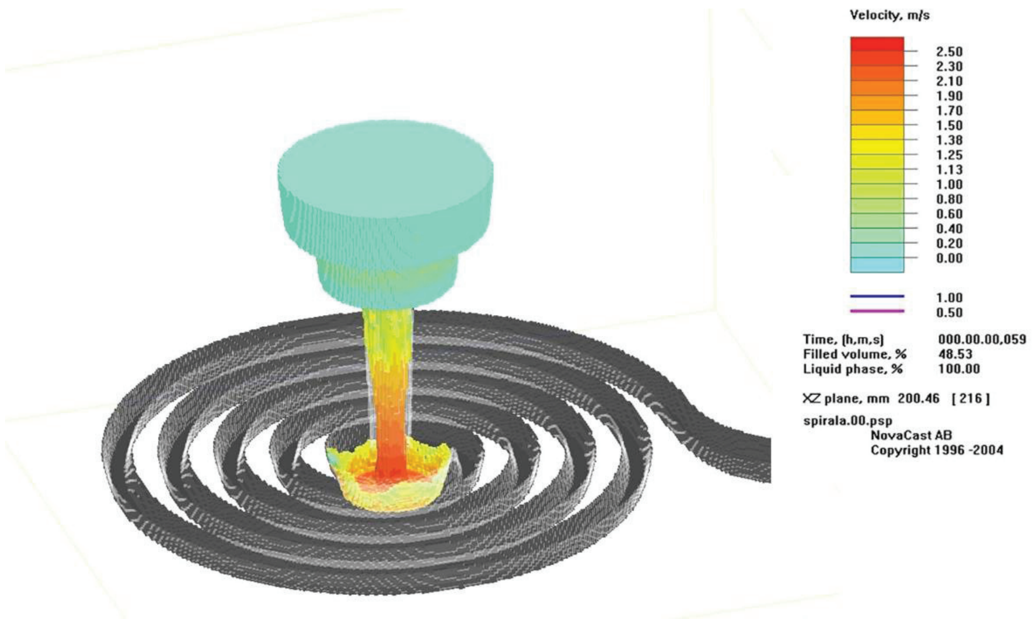

Figure 3 Velocity change of AlMg10 alloy in initial phase flow

From the simulation figures for the AlMg10 alloy it appears that in the initial phase of the flow the melt flow rate is very large and is at the bottom of the sprue about 2.3 m/s. Then the melt flow rate decreases to 0.6 m/s and then temporarily increases to 2.3 m/s. Then there is a quiet flow at a speed of about 0.4 m/s until the flow of the flow is stopped.

Figures 4 and **5** show the initial phase of the composite suspension flow. The cross-section (**Figure 4**) shows that the particles do not flow like the full stop with the sprue only flowing through the centre of the infusion. **Figure 5** shows the characteristic discontinuity of a stream of graphite particles in the alloy matrix. This is due to the construction of an gating system in which a large pouring basin is designed to retain solid inclusions in the metal stream. This effect is reflected in the simulation shown, where the graphite particles are retained in the pouring basin. In **Figure 5**, it can also be seen that particles flowing out of the gating system are chaotic but uniformly dispersed in the cast.

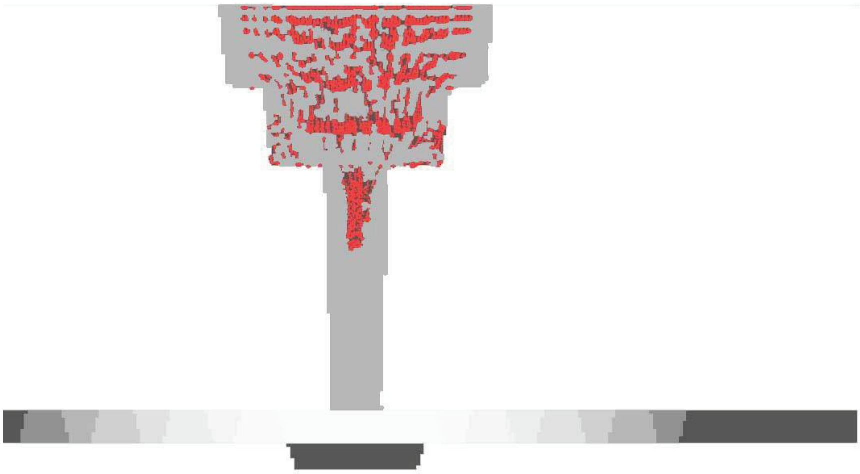

Figure 4 Initial stage of flow-cross section

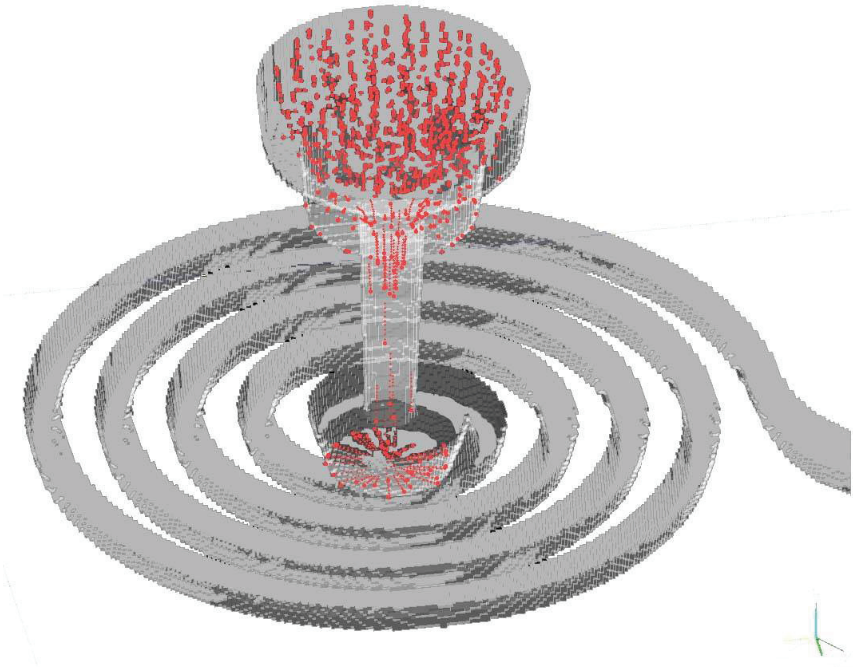

Figure 5 Initial stage of flow-3D view

At a later stage of the flow the particles are pushed through successive metal portions. **Figures 6-7** show particle distribution in the casting at the end of flow. **Figure 6** shows a 3D view, and **Figure 7** shows the cross-section of the cast. These figures show that most of the graphite particles are at the end of the spiral, the particles are pushed towards the end of the spiral casting. Particular movement of the particles upward at the end of the spiral cast can also be observed, as evidenced by earlier solutions of the particle motion equation in the mould channel.

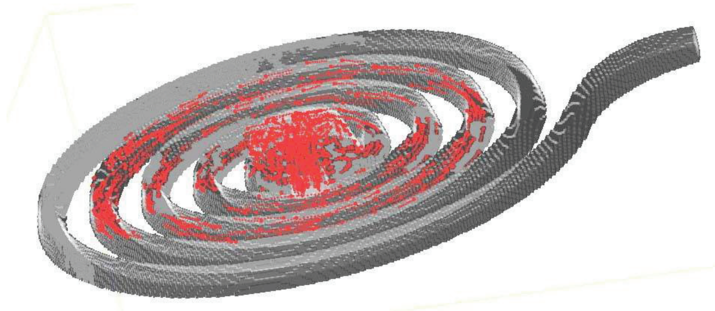

Figure 6 Distribution of graphite particles after flow finish-3D view

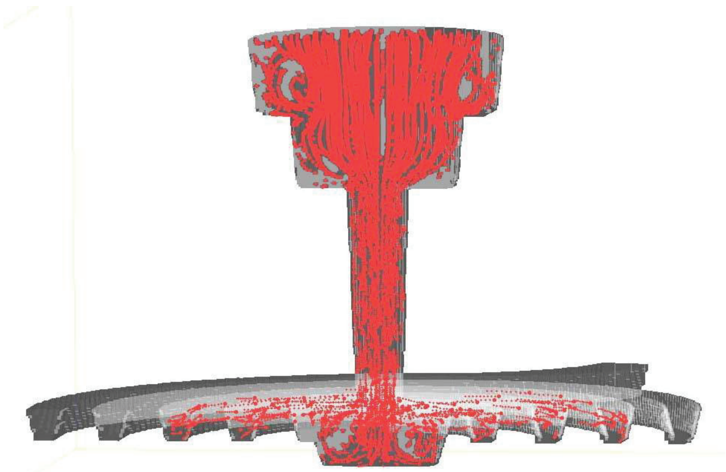

Figure 7 Distribution of graphite particles after flow finish-cross section

4. CONCLUSION

Metal matrix composites are used more and more often for the manufacture of machine parts or equipment. The requirements for these materials are, above all, high abrasion resistance, mechanical strength, heat resistance and resistance to high temperatures. On all of these properties are influenced primarily by the distribution of ceramic particles in the metal matrix. By predicting the particle distribution in the matrix we can predict the properties of the composite cast. These predictions can help us skillfully use simulation programs. By simulating the suspension flow, we can eliminate the risk of casting defects that determine casting quality and try to control the placement of particles by varying the flow parameters or the construction of the gating system or the shape of the composite casting itself. The simulated flow and distribution of graphite particles confirm the results obtained from direct measurements and calculations. Very similar results of the experiments presented in [11-13] were obtained by the authors of the above article which proves that the Nova Flow and Solid program is very useful for the design of foundry technology.

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