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Analysis of Defects in Castings Cast by Rheocasting Method SEED

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Abstract

The paper analyses specific defects of castings produced by semi-solid casting process, especially rheocasting method SEED, which uses mechanical swirling for reaching proper structure in semisolid state with high content of solid fraction. Heat treated alloy AlSi7Mg0.3 was applied for producing an Engine Bracket casting part. For observing structure, metallographic observation by light and SEM microscopy was used. To analyse the process, software ProCAST was used to simulate the movements in shot chamber and filling of the mold.

Keywords: Solidification process, Innovative foundry technologies and materials, Rheocasting, Casting defects, Simulation

1. Introduction

The handicap of the casting of aluminum alloys generally, especially HPDC, is the inner as-cast structure, often containing porosity, which can lead to lower mechanical properties of final parts comparing to other construction materials. To achieve higher values of mechanical properties, it is necessary to use some of progressive methods of casting, which ensure high integrity of casting parts.

One group of these methods is the semi-solid casting. The thixotropic properties were discovered more than 30 years ago. The possible advantages of applying these properties to process material in a semi-solid state were soon recognized and two different routes were proposed: thixocasting and rheocasting. There is presently a renewed interest in the semi-solid processing associated with the rheocasting route. However, the difficulty in obtaining a high-quality semi-solid material, together with the lack of a procedure for in situ measuring the rheological properties of the semi-solid slurry, has created some hurdles for the widespread use of the semi-solid casting technologies. [1]

The SEED process (Swirled Equilibrium Enthalpy Device) is one of those rheocasting processes in industrial production of semi-solid castings. The SEED process is based on achieving rapid thermal equilibrium between the metallic crucible and the bulk of metal by swirling. Morphology and size of the solid phase and the subsequent rheological properties of the semi-solid slurry are dependent upon the selected process parameters, including the pouring temperature and time of swirling in relation to the metal volume.

The special rheological properties of the semi-solid alloys are linked to a globular morphology of the solid phase, fundamental to achieving good quality final products. The key features of SEED method are quality improvements, such as production of high integrity shape complex parts with good inner quality suitable for structural applications, possibility of heat treatment of castings (blister free), parts are weldable, near-net-shape, thin and even thick wall pressure tight parts with geometrical flexibility, enhanced mechanical properties. There are also technological aspects, such as productivity improvement due to faster cycle rate, reduced total heat load on tooling, resulting in longer die life, returns can be fully recycled in the foundry. The SEED method principle is described in Figure 1.

Fig. 1. SEED rheocasting method principle – phases [2]

For semi-solid methods, alloys with wide two-phase interval, both hypo- and hyper eutectic are suitable [3]. Practically, hypoeutectic alloy AlSi7Mg0.3 is one of the most applied alloys. Compare to alloys Al-Si commonly used for HPDC, this alloy has less silicon and, what is important, less iron content, which contribute to enhanced mechanical properties.

In 2011 two workplaces of SEED method were installed in Kovolis Hedvikov, a.s. One of the projects cast by this method is the engine bracket casting. The goal of this work is to analyse specific casting defects appearing randomly on the casting surface after heat treatment mode T6 (see Figure 2).

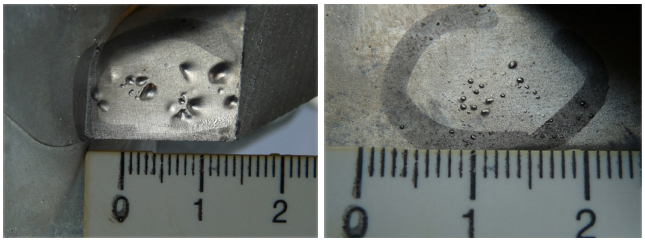

Fig. 2. Specific defects of casting appearing after heat treatment

2. Experiment

In this study, aluminum alloy EN-AC AlSi7Mg0.3 was used to produce semi-solid castings

with the SEED process. Chemical composition of the alloy is in Table 1. SEED and HPDC process parameters are described in Table 1. The casting was heat treated by complex heat treatment T6.

Table 1.
Chemical composition of experimental alloy EN-AC AlSi7Mg0,3

Si	Fe	Cu	Mn	Mg	Zn	Ti	Others	each	total
6.5 – 7.5	0.15	0.03	0.10	0.30 – 0.45	0.07	0.10 – 0.18		0.03	0.10

2.1. Metallography

Metallographic samples sectioned through the defects were prepared and observed by light microscope – see figures 3 - 5. The inner structure is shown in figure 6.

As can be seen, the defects are cavities under layer with different thickness. This layer is in several locations separated from the volume of the casting by oxide film (see e. g. Fig. 4). Oxide film and agglomerates can be also found in inner structure (e.g. Fig. 6).

The initial hypothesis to explain the cause of the defects assumed hydrogen blisters occurring after heat treatment, as it is known from conventional HPDC parts. Against this assumption goes the fact that the liquid metal was 3 times degassed and the density factor from the holding furnace was DI = 0,5 %. It is also confirmed by the metallographic observation: no characteristic hydrogen porosity or bubbles are present, only interdendritic shrinkage porosity can be found.

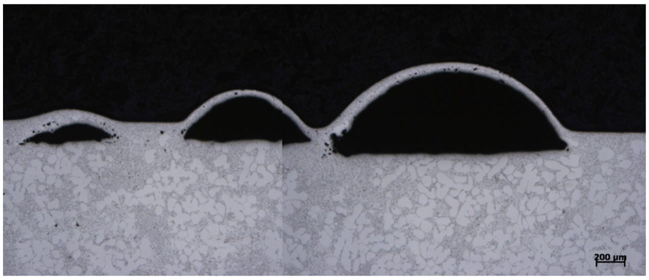

Fig. 3. Structure of the casting surface through the defects, 25x

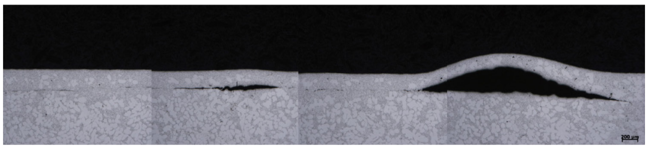

Fig. 4. Clearly visible oxide film between blister layer and the casting, 25x

Very interesting is the finding that the surface layer, not necessarily separated by oxide film, is mainly consisting of eutectic (see Fig. 5). This fact leads to the theory, that the defect is not actually the blister, but rollover of liquid eutectic phase during processing the semisolid slurry in the shot chamber and in the gating system. This hypothesis was confirmed by additional measurements of chemical composition of the castings. 8 different castings were analyzed on the surface, and the content of silicon varied from 9,8 % up to 13,98 % Si, average value is 12,6 %Si (compare with the the used alloy value 7 %), what corresponds to eutectic composition (12,2 % Si).

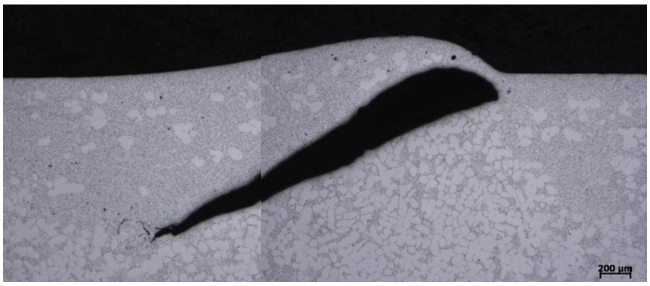

Fig. 5. Layer of eutectic structure covering the defect, 25x

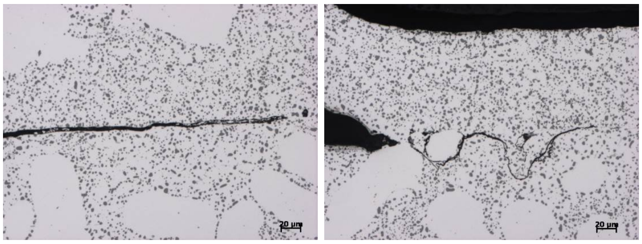

Fig. 6. Inner structure containing oxide films, 200x

To analyse the process in shot chamber and during filling of the mold, simulation software ProCAST was used in comparison with “stop tests” of the real process (see Fig. 7 and 8).

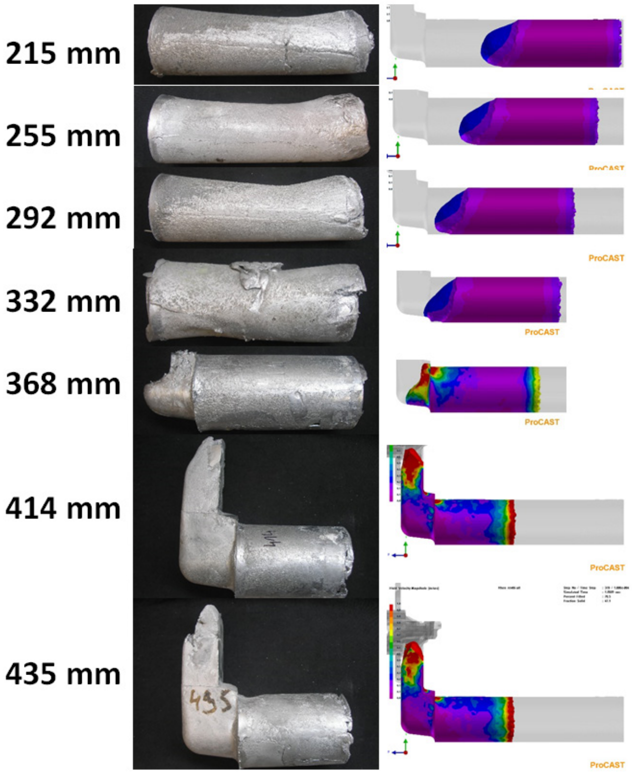

Fig. 7. Stop tests and simulation of the movements in shot chamber in selected positions of the piston

The results of simulation of the piston movement and mold filling were in quite good conformity with the reality observed by the stop tests. Only difference is the creation of the concave flowing profile forehead of the flow appearing on simulation results in comparison with flat forehead visible on stop tests. Filling of the mold was identical both in simulations and stop tests.

But the simulation did not show any finer details of surface layers of the semisolid slurry during movements through the shot chamber to explain the specific roll overs creating the defects. To analyse these phenomena, different software and numerical model should be used.

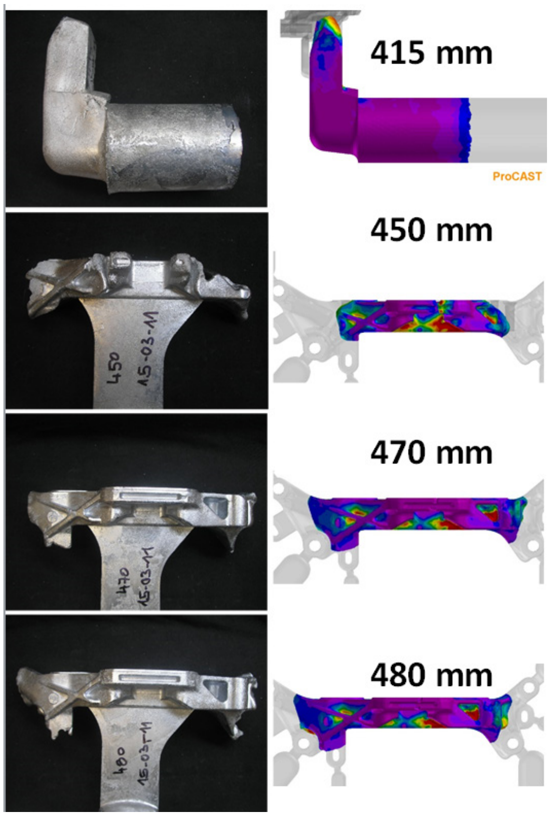

Fig. 8. Stop tests and simulation of the filling of the mold in selected positions of the piston

3. Discussion of results

Specific defects of parts made of alloy AlSi7Mg0,3 (T6) processed by rheocasting method SEED were analyzed. It was found, that the structure contains phase segregation, specifically rollovers of eutectic phase locally bounded by oxide film.

This phenomenon is due to the two phase composition of semisolid intermediate product slurry, which is consisting of solid primary α(Al) phase and liquid eutectic (α+β) phase. Even if the whole slurry has compact shape with consistency similar to butter and generally acts as a pseudo plastic stuff , during processing of the slurry (what is mainly dosing to the shot chamber, movements in the chamber under pressure of the piston and filling and moving through the gating system to the mold) can these two phases separate, the eutectic can drain out resulting following process complications:

- rollovers of eutectic phase, which are after the heat treatment lifted by the expansion of residual hydrogen
- oxide films, which create structural discontinuities causing decreasing of mechanical properties and e.g. leakage
- local differences of chemical composition

4. Conclusions

The rheocasting procees, even if it is partly consisting of high pressure die castig process, is specific from viewpoint of characteristic intermediate product as called "slurry", which is semisolid pseudo plastic stuff consisting of solid α(Al) phase and liquid eutectic (α+β) phase, and its dosing to the shot chamber followed by pressing forward by the piston. Even if the slurry holds the shape of the vibrating and dosing crucible, those two phases can separate affected by gravity or movement and in result it can lead to such specific defects as analysed in this paper.

To avoid these specific casting defects, it is necessary to focus on the slurry processing, especially dosing to the chamber, piston movement parameters in relation to the slurry shifting in the chamber, optimization of the gating system construction. Also the lubrication of piston and chamber significantly affect the quality of casting surface. These issues are the subjects of solving in further works.

Acknowledgements

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