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Using of Technology Semisolid Squeeze Casting by Different Initial States of Material

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Abstract

The paper deals with the effect of heating of various prepared batch materials into semisolid state with subsequent solidification of the cast under pressure. The investigated material was a subeutectic aluminium alloy AlSi7Mg0.3. The heating temperature to the semisolid was chosen at 50% liquid phase. The used material was prepared in a variety of ways: heat treatment, inoculation and by squeeze casting. Also the influence of the initial state of material on inheritance of mechanical properties and microstructure was observed. The pressure was 100 MPa. Effect on the resulting casting structure, alpha phase distribution and eutectic silicon was observed. By using semisolid squeeze casting process the mechanical properties and microstructures of the casts has changed. The final microstructure of the casts is very similar to the microstructure that can be reached by technology of thixocasting. The mechanical properties by using semisolid squeeze casting has been increased except the heat treated material.

Keywords: Innovative foundry technologies and materials, Solidification process, Squeeze casting, Aluminium alloy AlSi7Mg0.3, Crystallisation under pressure

1. Introduction

Using of lightweight metals, especially in automotive and transport industries had risen in last four decades and consequently, also processing techniques have been developed to improve properties of lightweight metals alloys. One of this techniques is Semisolid metal (SSM) processing. SSM processing combines the advantages of casting and conventional hot forging and has been considered as one of the most promising technologies of the 21st century [1–5]. The origins of semisolid metal processing can be traced to the experiments conducted by David Spencer at Massachusetts Institute of Technology in 1971. Today, after more than four decades of research, this metal processing technology has been used to commercially produced casts that require a high integrity [6].

In the treatment of the metal in semisolid state there are three major possibilities: thixocasting, rheocasting and thixomolding. They differ in particular by the various methods of preparing the material into semisolid state. The thixocasting method consists in the special preparation of a non-dendritic semifinished material with a fine-grained structure, which is allowed to fully solidify. Before filling the mould cavity, it is melted into a partially solid state by induction heating. Rheocasting uses intensive mixing of the conventionally used alloy during solidification. Thixomolding can be used for magnesium alloys, where magnesium granules from 1 to 4 mm are delivered to the mould cavity using a threaded extruder. This causes high shear stresses and together with the effect of external heat, a semisolid suspension is produced [6].

There are several advantages by using the technology of semisolid metal processing:

- Extending mould life. The metal slurry contains about 50% of the solid phase during casting, which means that a considerable amount of heat from the phase conversion has been released before injection into the mould cavity, thereby significantly reducing its thermal load.
- Reducing the time required for one casting cycle, since by reducing the energy released during solidification, the setting time is reduced by almost half.
- Reducing the impact of the shrinkage process.
- Increasing casting integrity and improving mechanical properties [6].

The main step in SSM processing is to generate metal slurry that exhibits thixotropic behaviour and contains a globular primary phase. A typical structure of aluminium alloy A356 (AlSi7Mg0.3) in semisolid state consisting of globular alpha-aluminium surrounded by eutectic is described on figure 1 [6].

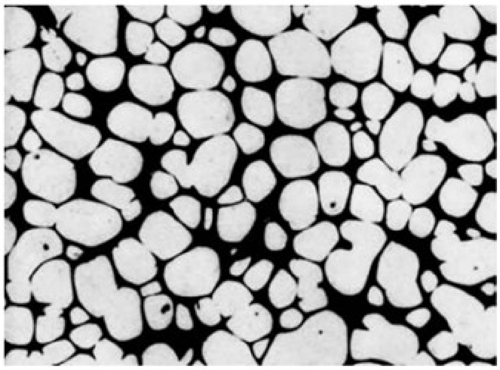

Fig. 1. Typical semisolid structure of A356 alloy

Technology of Semisolid squeeze casting (SSSC) combines semisolid forming and squeeze casting to improve conventional squeeze casting. This technology was summarized by Ghomashchi and Vikhrov [7]. The influence of squeeze casting technology on microstructure and mechanical properties of aluminium and magnesium alloys has been extensively investigated in several works [8-14]. Nowadays, research has been applied SC technology in SSM processing of aluminium alloys.

The main purpose of this paper is to experimentally verify the SSSC technology and observe the inheritance in mechanical properties and microstructure in relation to method of sample preparation.

2. Experiment methodology

As experimental method of SSM processing has been selected method of semisolid squeeze casting. As experimental material was used the AlSi7Mg0.3 alloy. The chemical composition of used alloy is shown in table 1.

Table 1.
Chemical composition of used AlSi7Mg0.3 alloy [wt. %]

Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
7.01	0.19	≤ 0.01	0.02	0.31	≤ 0.01	0.12	Bal.

Samples from this alloy were created by gravity casting into a metal mould. For observation of inheritance in microstructures and mechanical properties of samples were some of them inoculated with 0.2 wt. % of AlTi5B1 to achieve a finer grain structure compared to non-inoculated samples. Another samples were heat treated with dissolution annealing to alter the distribution of eutectic silicon in the microstructure as well as to change the mechanical properties. Annealing temperature was 540 °C, time 6 hours, cooling to water with 60 °C. In addition to the gravitationally casted samples, were created samples by squeeze casting. These samples were not inoculated or further heat treated. All samples were then machined into round bars of desired dimensions. Prepared samples were placed in jigs made from low carbon steel. The surface of the die cavity and the surface of the samples themselves was treated with a graphite coating. The semisolid state of the samples was achieved by heating them to a temperature with 50% of liquid phase. The heating was carried out by placing the samples in steel jigs in a resistance chamber furnace, which had been preheated to a required temperature. The heating of the samples was monitored using K-type thermocouples located in the control sample. After reaching the desired temperature, the specimens were individually extruded on a conventional hydraulic press into circular cross-section mould. The pressure applied to the sample was set on 100 MPa. Schematic composition of single parts by executing experiment is described on figure 2.

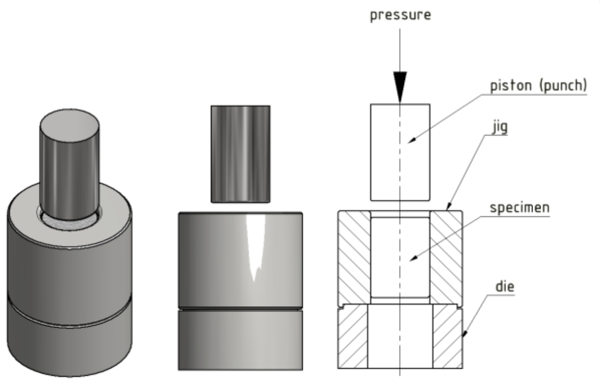

Fig. 2. Parts of experimental mould

During the experiment, none of the technological parameters were varied. Casting temperature was set to level with 50% liquid phase, i.e. 578 °C and mould temperature was set to 200 °C.

3. Results

From individual samples were created figures of microstructure before and after semisolid squeeze casting process. Also samples to evaluate a mechanical properties were prepared.

3.1. Assessment of microstructure

On figures 3-6 are shown microstructures of individual samples. Each figure describes one sample in its initial level and after semisolid squeeze casting process. All figures were taken at 50x magnification.

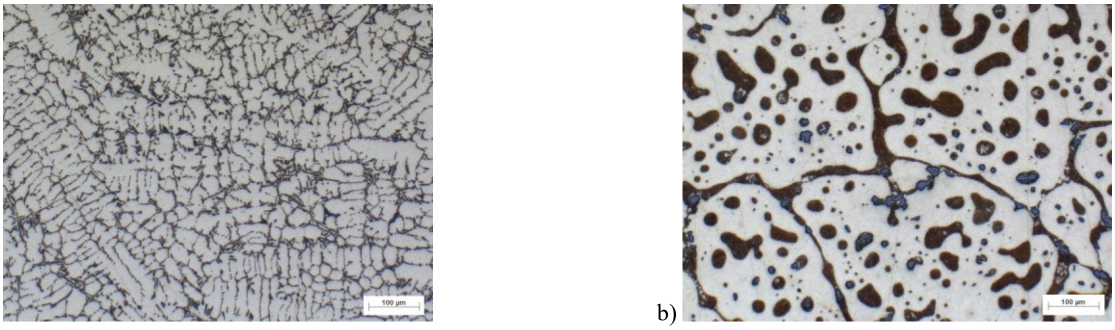

Figure 3. Microstructure of AlSi7Mg0.3 alloy, gravity casted (a) and after SSSC (b)

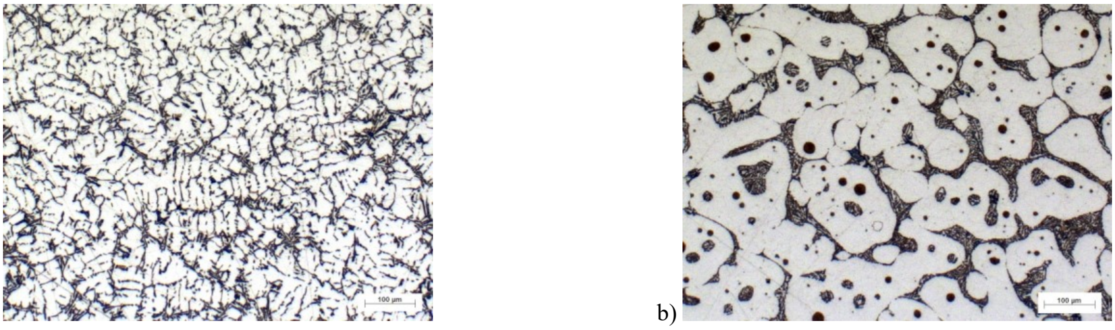

Figure 4. Microstructure of AlSi7Mg0.3 alloy, inoculated (a) and after SSSC (b)

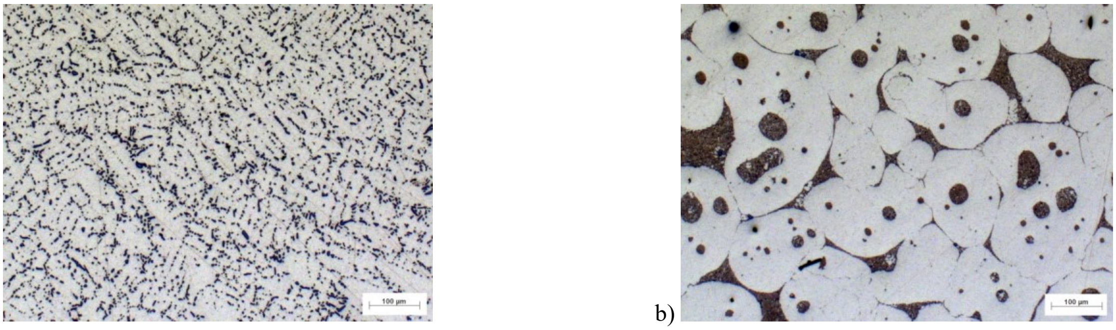

Figure 5. Microstructure of AlSi7Mg0.3 alloy, heat treated (a) and after SSSC (b)

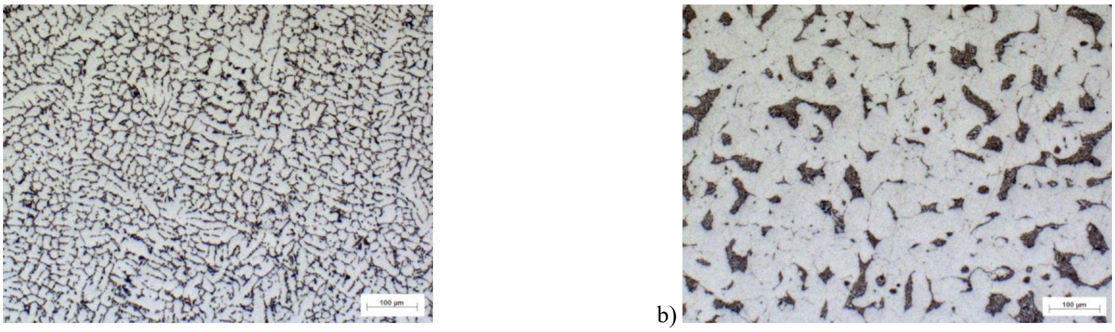

Figure 6. Microstructure of AlSi7Mg0.3 alloy, squeeze casted (a) and after SSSC (b)

The microstructure of AlSi7Mg0.3 alloy is composed of an alpha aluminium phase and a eutectic silicon. There are remarkable changes between individual initial states of material. The influence of the inoculation or heat treatment by preparing the material can be observed on the size of the alpha phase grain and on shape and distribution of eutectic silicon. Inoculated sample has fine grain microstructure with short dendritic grains. Due to the heat treatment, the shape of eutectic silicon changed from lamellar to globular. After using the technology of semisolid squeeze casting the microstructure has been changed. The final microstructure of the casts is very similar to the microstructure that can be reached by technology of thixocasting. Morphology of alpha phase grains has changed from dendrites to globular grains. The eutectic silicon is distributed along boundaries of alpha phase grains and by gravity casted, inoculated and heat treated sample also inside the alpha phase grains.

3.2. Evaluating of mechanical properties

In table 2 are shown average values of the mechanical properties of samples before and after semisolid squeeze casting process. It can be observed changes in mechanical properties due to the different method of preparation.

Table 2.
Values of mechanical properties of individual samples

	Before semisolid squeeze casting		
Preparation method	Gravity casted	Inoculated	Heat treated
R_m [MPa]	179	206	244
A [%]	2.27	2.09	4.05
	After semisolid squeeze casting		
Preparation method	Gravity casted	Inoculated	Heat treated
R_m [MPa]	200	223	203
A [%]	3.09	2.65	5.68

It can be concluded from the results, that the gravity casted and inoculated samples obtained after SSSC process higher strength and plastic properties compared with state before SSSC process. Tensile strength increased by 11.7 % (gravity casted) and 8.3% (inoculated). Ductility increased by 36.1% (gravity casted) and 26.8% (inoculated). Heat treated samples obtained after SSSC process lower strength by 16.8% but ductility increased by 40.2%.

4. Conclusions

Technology of semisolid squeeze casting has been experimentally verified. By the experiment was observed the influence of this production technology on mechanical properties and microstructure of the samples. Also the influence of the initial state of material on inheritance of mechanical properties and microstructure was observed. It can be concluded that by using semisolid squeeze casting process the mechanical properties and microstructures of the casts has changed. The mechanical properties by using semisolid squeeze casting has been increased except the heat treated material. By this material can be observe the decrease of tensile strength but the ductility has been increased. This decrease in mechanical properties was probably caused by the reverse change of eutectic silicon from globular to lamellar shape. On this basis, it can be concluded that the most significant impact on inheritance of mechanical properties and microstructure after SSSC has the initial state of alpha aluminium phase. Eutectic silicon is always segregate in lamellar shape.

Acknowledgements

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