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THE INFLUENCE OF THE MODIFIED ABLATION CASTING ON CASTS PROPERTIES PRODUCED IN MICROWAVE HARDENED MOULDS WITH HYDRATED SODIUM SILICATE BINDER

The ablation casting technology consists in pouring castings in single-use moulds made from the mixture of sand and water-soluble binder. After pouring the mould with liquid metal the mould is destructed (washed out) using a stream of cooling medium, which in this case is water. The process takes place while the casting is still solidifying.

The following paper focuses on testing the influence of the modified ablation casting of aluminum alloy on casts properties produced in moulds with hydrated sodium silicate binder. The authors showed that the best kind of moulding sands for Al alloy casting will be those hardened with physical factors – through dehydration. The analysis of literature data and own research have shown that the moulding sand with hydrated sodium silicate hardened by dehydration is characterized by sufficient strength properties for the modified ablation casting of Al alloys. In the paper the use of microwave hardened moulding sands has been proposed.

The moulds were prepared in the matrix specially designed for this technology. Two castings from the AlSi7Mg alloy were made; one by traditional gravity casting and the other by gravity casting using ablation.

The conducted casts tests showed that the casting made in modified ablation casting technology characterizes by higher mechanical properties than the casting made in traditional casting technology. In both experimental castings the directional solidification was observed, however in casting made by ablation casting, dimensions of dendrites in the structure at appropriate levels were smaller.

Keywords: Moulding sand, Ablation casting, Hydrated sodium silicate, Microwave hardening, Mechanical properties of casting

1. Introduction

Ablation casting is a term taken probably from the Latin word ablatio meaning removal or ablutio which means washing. The essence of the ablation casting technology consists in pouring castings in single-use moulds made from the mixture of sand and water-soluble binder. After pouring the mould with liquid metal, while the casting is still solidifying, the mould destruction (washing out, erosion) takes place using a stream of cooling medium, which in this case is water.

China is considered to be the precursor of ablation casting technology. This technique was used to produce dish handles from around 1600 BC [1].

In 2006, Alotech company patented a casting stand using the ablation casting method [2-3]. The sand mould was located on a conveyor belt and after being poured with liquid metal it moved horizontally to a set of spray nozzles, where under high water pressure it was broken down.

At the Foundry Research Institute in Krakow, a modification of the casting stand for ablation casting was introduced [4-5]. The device construction allows for rotation and vertical plane movement, which ensures simultaneous removal of the moulding sand from the mould by a stream of water supplied from the nozzles and controlled directional cooling of the casting.

Ablation casting technology offers a number of advantages. Among others, it eliminates an additional operation of casting knocking out from the mould avoiding the dust pollution in a foundry.

Furthermore there is no air gap between the mould and the surface layer of the cooled casting, which limits the heat flow to the outside. This enables solidification of liquid metal under conditions of unprecedentedly large temperature gradient and high crystallization rate. The mechanical properties of the obtained castings are equal to or higher than the level of analogical characteristics obtained in the pressure die casting process [1]. Another advantage of this innovative technology is

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controlled directional solidification, which eliminates shrinkage porosity.

It is also worth mentioning the economic factor of the process of producing high-quality castings in compact, ceramic moulds in relation to high-cost of metal mould technologies. Another advantage is an ecological factor related to the use of an inorganic water-soluble binder.

2. Selection of moulding sands for single-use ceramic moulds designed for the modified ablation casting

The moulding sand used in the modified ablation casting process should be characterized by durability that allows transfer of the hydrostatic pressure of the liquid metal while being susceptible to the destructive effect of the cooling medium [6]. The use of hydrated sodium silicate as a binder for ablation casting technology is therefore justified. The inorganic binder is water-soluble and is therefore environmentally friendly. The ecological character of moulding sands is currently the basic criterion for their development [7-11].

Hydrated sodium silicate as a foundry moulding sand binder was first used in 1947 by L. Petržela (Czech patent no. 81931).

The ecological nature of the binder makes it the object of many current studies and modern technologies using hydrated sodium silicate are increasingly used in foundry practice. The previous work of the authors [7,11] concerned the development of moulding sands with hydrated sodium silicate hardened in ester technology with increased knock-out properties and ensuring a better quality of reclaim.

From the standpoint of knock-out properties, the use of moulding sands with hydrated sodium silicate for the ablation casting of aluminum alloys is fully justified. The pouring temperature of the liquid casting alloy coincides with the temperature at which there is a minimum retained strength R_c^{tk} of the moulding sands with hydrated sodium silicate (600°C). Although in ablation casting technology water will support both the knocking-out properties and mechanical reclamation of moulding sands, nevertheless this argument additionally supports the use of moulding sands with hydrated sodium silicate on ceramic moulds for aluminum casting.

In the case of ablation casting, however, the possibility of applying physical hardening to the moulding sands with hydrated sodium silicate should be considered. This is important from the point of view of the water recovered in the process, as well as the utilization of waste water. The elimination of chemical hardening of the moulding sands will additionally have a positive effect on the ecology of the process. The use of physical hardening could allow to recover, not only the matrix, but also a part of the binder.In previous studies, the authors proposed the use of microwave curing. The research [7,12-13] shows that the technology of microwaved hardened moulding sands with hydrated sodium silicate allows for a significant reduction of the amount of binder while maintaining appropriate strength properties of moulding sands.

3. Experimental procedure and results

As part of own research, the influence of the modified ablation casting on casts properties produced in microwaved hardened moulds with hydrated sodium silicate binder was determined. For this purpose a design of the matrix to make the mould intended for gravity ablation casting was made. The ratio of the outside diameter of the mould to the cast diameter is from 100 : 50 to 120 : 50. The matrix was made of alder wood (Fig. 1).

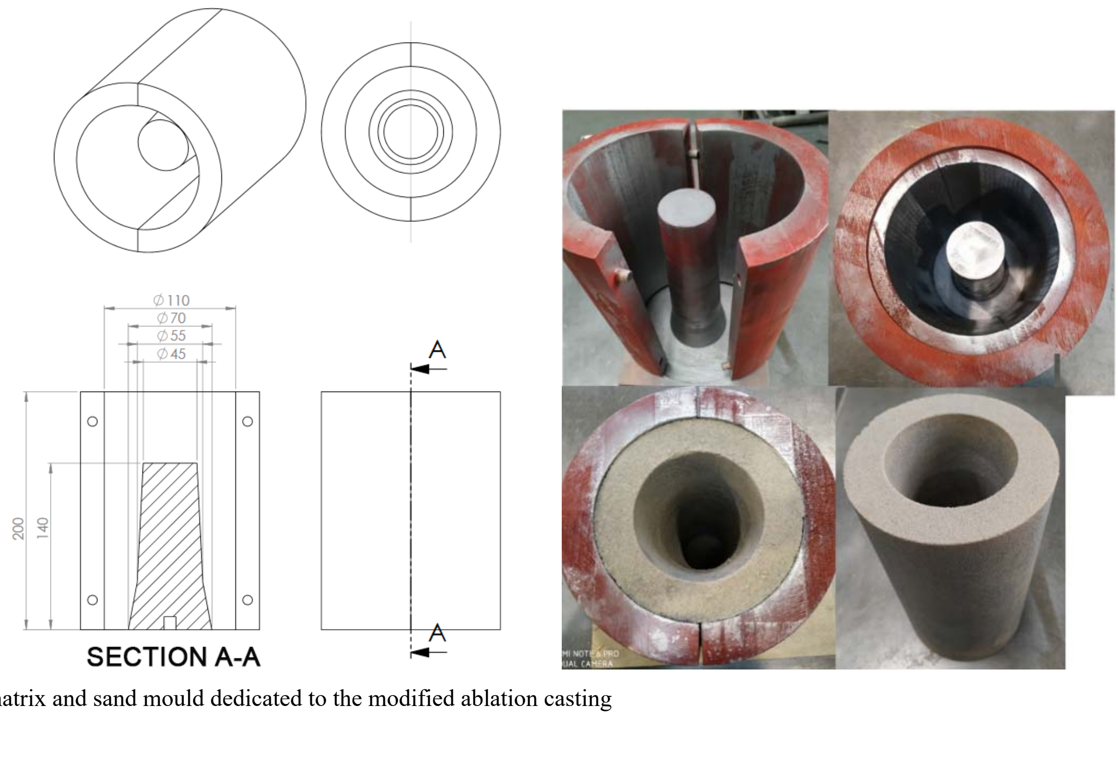


Fig. 1. The matrix and sand mould dedicated to the modified ablation casting

Two experimental casts were prepared using the designed matrix in two moulds from moulding sands with hydrated sodium silicate hardened by dehydration in microwave technology. Table 1 shows selected physicochemical properties of hydrated sodium silicate used as a binder are presented [14].

TABLE 1

Physicochemical properties of hydrated sodium silicate (145 water glass) [14]

Property / unit	145 water glass
form	water solution
physical condition	liquid
colour	colourless
smell	odourless
$Na_2O + SiO_2$ / %	39
SiO_2/Na_2O	2.5
Density (in temp. 20°C) / g/cm^3	1.45-1.48
Dynamic viscosity (in temp. 20-25°C) / mPa·s	20-40

Moulding sands composition used to prepare experimental moulds are presented below.

Quartz sand 100 p.p.w.
Binder 1.5 p.p.w.
Water 0.5 p.p.w.

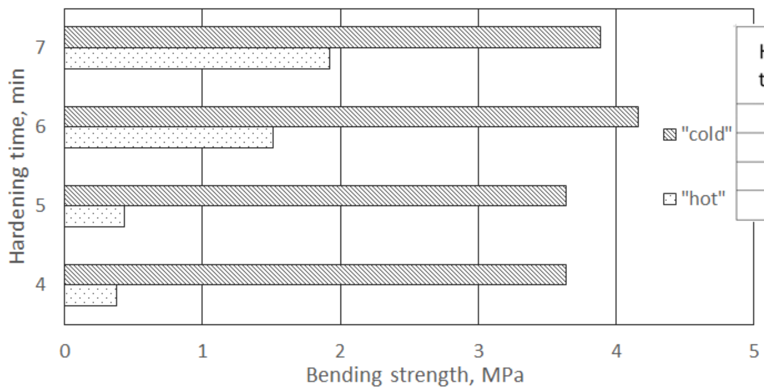
Quartz sand from the Grudzeń Las Sand Mine was used in all of the conducted tests. According to the Polish standard PN-85/H-11001 the tested sand was classified as medium (main fraction 0,20/0,16/0,315).

The moulding mixtures were prepared in a Multiserw-Morek laboratory mixer, with a capacity of 8 kg. Mixing parameters were: sand and water were mixed for 90 seconds and, after adding the binder, the moulding sand was mixed for another 90 seconds. Hydrothermal conditions, in which mixtures were prepared and moulds were stored, ranged between 23-25°C and 42-45% humidity. The hardening process was conducted by 800 W microwaves in 4-7 min. Bending strength of the samples was tested just after hardening ("hot") and after 1h ("cold"). The results of the tests are shown in Figure 2.

As a part of this work, a moulding sand hardened for 5 minutes was selected for further tests.

Investigations of hardened moulding sands showed that the binder flowed into the contact point of the sand grains creating binding bridges (Fig. 3). It is very beneficial from the point of view of the amount of used binding material and subsequent regeneration of the used moulding sands. This phenomenon will be the subject of further research.

The next stage of the research was the production of castings. Mould 1 was gravitationally poured without the use of ablation, and mould 2 was gravitationally poured using ablation casting technology. Both moulds were poured with an AlSi7Mg alloy from one melt. The pouring temperature was 717°C. In the case of mould 2 the ablation was started after 15 sec from the



Hardening time / min	Bending strength / MPa	
	"hot"	"cold"
4	0.38	3.64
5	0.43	3.64
6	1.51	4.16
7	1.92	3.89

Fig. 2. The influence of microwave hardening time on bending strength of moulding sands with hydrated sodium silicate

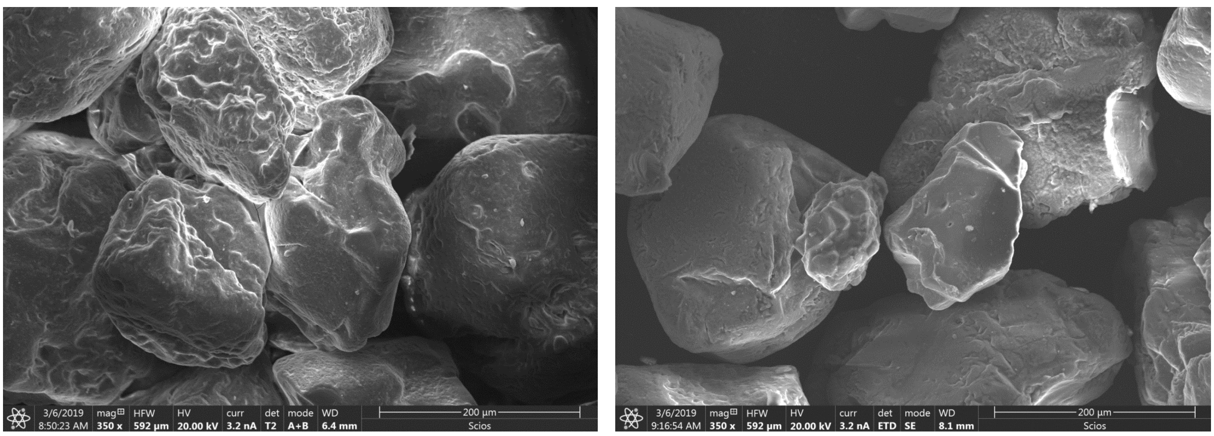
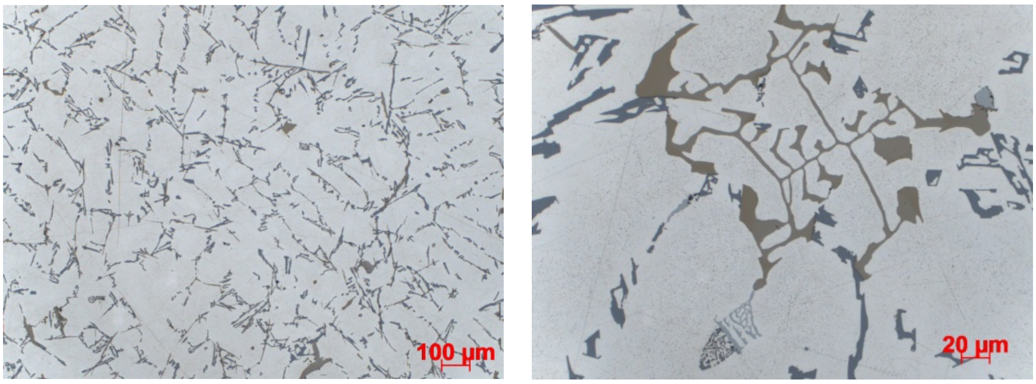
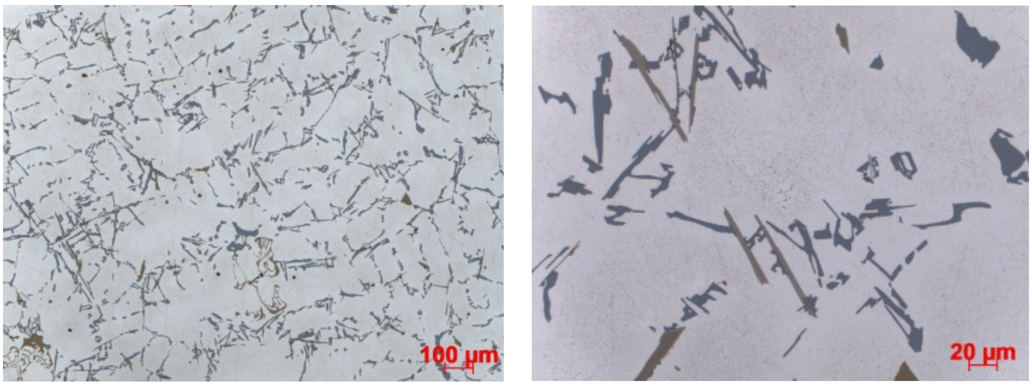


Fig. 3. Binding bridges in the moulding sand with hydrated sodium silicate hardened by microwaves

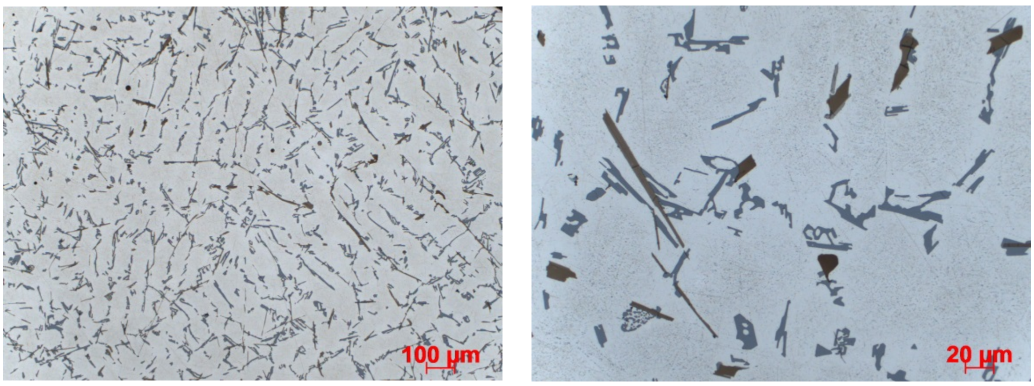
Fig. 4.The experimental cast in the modified ablation casting: A) sand mould, B) ablation process, water erosion, C) ready casting, D) cut casting with marked measurement levels



Level 3 (upper part of casting)



Level 2 (middle part of casting)



Level 1 (bottom part of casting)

Fig. 5. Microstructure of casting AlSi7Mg alloy made by the gravity casting

beginning of the pouring. The ablation medium was a tap water at the ambient temperature. Destruction of the mould occurred after 2.45 minutes of washing out with water.

The technology of making a sand mould used for the ablation casting, especially from non-ferrous alloys, is covered by [4-5]. Figure 4 presents selected stages of making a cast in ablation casting technology.

Castings obtained in the mould 1 (casting without ablation) and in the mould 2 (ablation casting) were subjected of laboratory analysis.

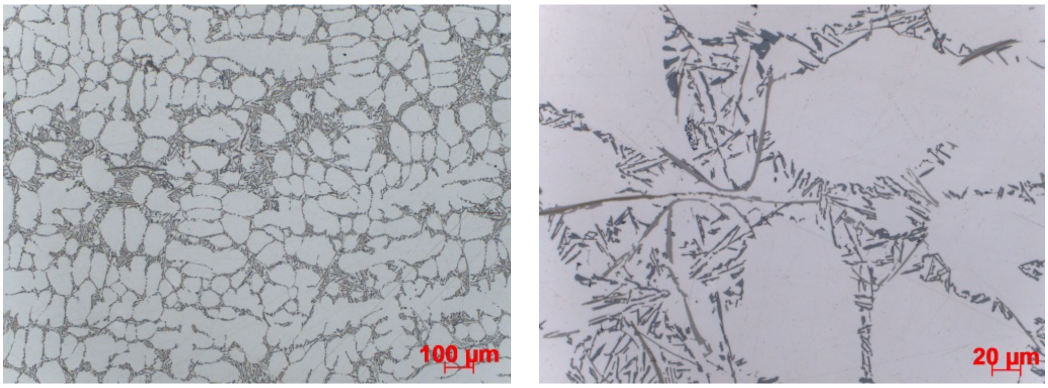
The microstructure of the experimental castings was examined at three levels of the casting height at a magnification of 100× and 500× (Fig. 5 and 6). Microstructure examinations were carried out on metallographic specimens etched in a 1% HF reagent using the Zeiss Axio Observer Z1m light microscope.

Tensile properties of casting AlSi7Mg alloy were determined by PN-EN ISO 6892-1:2016-09 testing standard. Examinations were carried out on Instron 8800M strength testing machine.

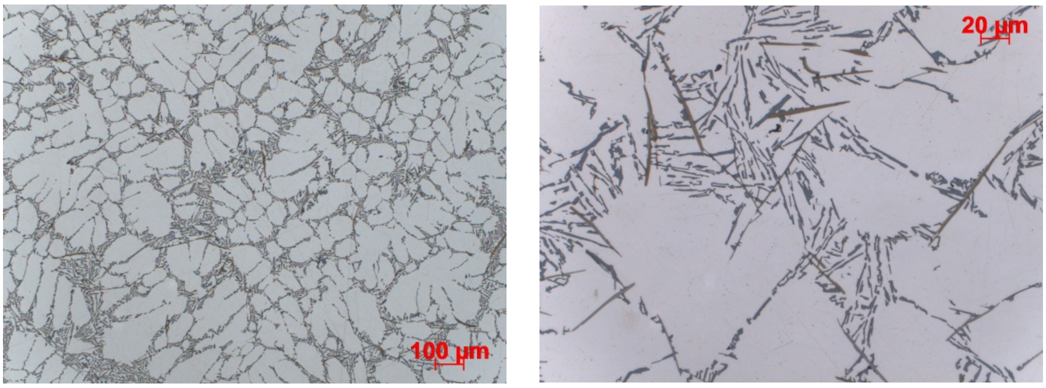
The casting made in the mould 1 (casting without ablation) is characterized by the occurrence of dendrites with the following dimensions: 84 μm (bottom part), 96 μm (middle part) and 110 μm (upper part). Its mechanical properties were: YS = 34 MPa, UTS – 110 MPa, A = 4.8%.

The cast made in the mould 2 (ablation casting) is characterized by the occurrence of dendrites with the following dimensions: 63 μm (bottom part), 94 μm (middle part) and 97 μm (upper part). Its mechanical properties were: YS = 33 MPa, UTS – 156 MPa, A = 4.8%.

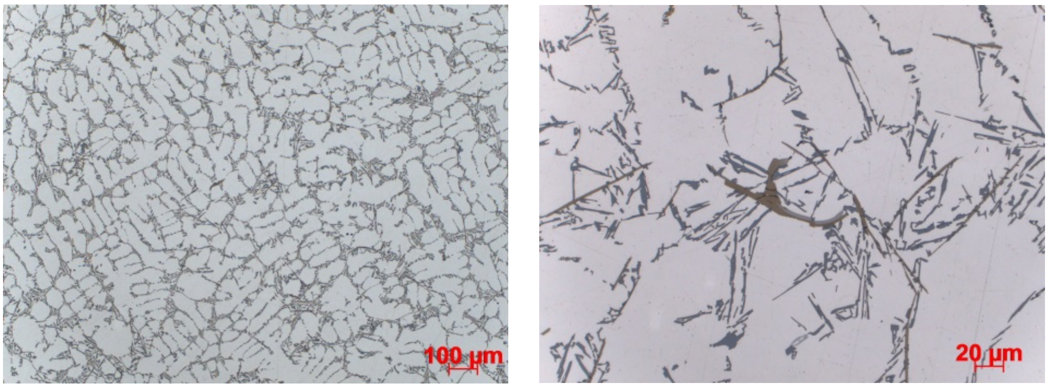
Literature data [15] state that the AlSi7Mg alloy, without the thermal treatment, has min. UTS = 160 MPa, A5 = 2% and



Level 3 (upper part of casting)



Level 2 (middle part of casting)



Level 1 (bottom part of casting)

Fig. 6. Microstructure of casting AlSi7Mg alloy made by the modified ablation casting

hardness 60 HB. However, these properties depend on the type of cast and the conditions of its solidification. The mechanical properties of the AlSi7Mg alloy are resulted by an unfavorable structure. In the unmodified state, it has hard, undeformable eutectic grains of a solid aluminum solution in silicon (β) against a plastic solution of solid silicon in aluminum (α). This structure is the reason for low elongation values.

4. Conclusions

Literature analysis and own research allowed to formulate the following conclusions:

- The use of moulding sands with water-soluble hydrated sodium silicate as a binder for ablation casting is fully justified.
- It is possible to use moulding sands with hydrated sodium silicate prepared in various technologies. However, from the point of view of ablation casting technology, the most desirable is the use of moulding sands hardened with physical factors.
- The designed matrix ensures the production of a mould with parameters ensuring the directional solidification of the cast during the ablation process.
- The conducted castings tests showed that the cast made in modified ablation casting characterizes by higher mechanical properties than the cast made in traditional gravity casting.
- In both experimental casts the directional solidification was observed, however in cast made in ablation casting, dimensions of dendrites in the structure at appropriate levels were smaller.

The presented results are part of a broader, ongoing research concerning mechanical and thermal behaviour of various types of moulding and core sands.

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