

The Use of Floster S Technology in Modified Ablation Casting of Aluminum Alloys

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Abstract

Ablation casting is a technological process in which the increased cooling rate causes microstructure refinement, resulting in improved mechanical properties of the final product. This technology is particularly suitable for the manufacture of castings with intricate shapes and thin walls. Currently, the ablation casting process is not used in the Polish industry.

This article presents the results of strength tests carried out on moulding sands based on hydrated sodium silicate hardened in the Floster S technology, intended for ablation casting of the AlSi7Mg (AK7) aluminium alloy. When testing the bending and tensile strengths of sands, parameters such as binder and hardener content were taken into account. The sand mixtures were tested after 24h hardening at room temperature. The next stage of the study describes the course of the ablation casting process, starting with the manufacture of foundry mould from the selected moulding mixture and ending in tests carried out on the ready casting to check the surface quality, structure and mechanical properties. The results were compared with the parallel results obtained on a casting gravity poured into the sand mould and solidifying in a traditional way at ambient temperature.

Keywords: Moulding sands, Ablation casting, Water glass, Floster S, Mechanical properties of casting, Surface quality

1. Introduction

Ablation casting is a modern technology of casting into foundry moulds that are intensively cooled during casting solidification. The process was patented by Alotech in 2006 and its essence consists in this that the alloy is cast into a sand mould and when it is still in a liquid state, the mould is being washed from a certain distance with jets of the cooling medium until full desintegration of the moulding material takes place [1-3]. Castings made by this technology are used in the automotive industry as parts of the bodywork, in the crushing zone, or as connecting links of the frame beams. Their use reduces vehicle weight and improves anti-collision protection [4]. A characteristic

feature of this process is the direct contact of water with the surface of the casting, eliminating the occurrence of a gas gap typical of all other casting methods and reducing heat transfer from the casting to the outside. A large temperature gradient on the casting cross-section allows avoiding the occurrence of shrinkage porosity, while the solidification process under the conditions of rapid heat removal produces casting with a very fine microstructure [5-7]. Therefore, this technology is mainly applicable to castings with intricate shapes and diversified wall thicknesses made in sand moulds, in which a lower cooling rate may cause unfavourable grain growth [8].

Nowadays, in the foundry industry, more and more attention is paid to the process ecology, and for this reason, inorganic

binders are enjoying increasing popularity [9-12]. Hydrated sodium silicate is such a binder. This material was used for the first time by L. Petržela in 1947 and the process was described in Czech Patent No. 81931. The sand hardening process took place by blowing the sand with CO₂. To carry out this process, up to 8 parts by weight of binder were used, making the sand mixture hardly collapsible. The breakthrough took place in 1968, when the process using liquid hardeners was developed. This allowed reducing the addition of binder to 3 parts by weight. The result was improved sand collapsibility with successfully maintained high strength properties [13-15]. Hydrated sodium silicate is a water-based binder, which guarantees the sand mould susceptibility to leaching with ablation medium, as confirmed by previous own studies [6].

2. Studies of moulding sands

To select the optimal composition of moulding sand, bending and tensile tests were carried out on samples with three different binder contents (2.0, 2.5, 3.0 parts by weight) and three different hardener contents (8; 10, 12% relative to the amount of binder) hardened at room temperature for 24 hours. The sand mixtures were prepared by the traditional Floster S technology, using sodium water glass grade R145 as a binder and Flodur 3 as a hardener. Binder R145 is hydrated sodium silicate with a SiO₂ / Na₂O molar module of 2.4÷2.6. Flodur 3 is a liquid hardener, an ester of ethylene glycol diacetate modified with the addition of a catalyst.

Figures 1 and 2 present the results of strength tests carried out on sands with various contents of water glass grade R145 and hardener.

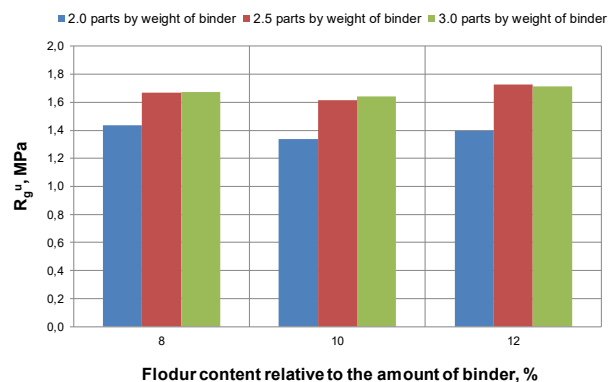


Fig. 1. Bending strength R_g^u after 24h hardening using various contents of water glass and hardener

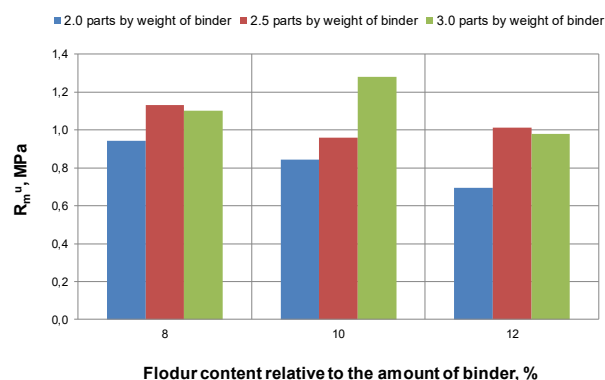


Fig. 2. Tensile strength R_m^u after 24h hardening using various contents of water glass and hardener

The results of earlier tests have shown that the moulding sand for ablation casting should have the strength sufficiently low to allow the ablation medium (water) to break down the mould completely, but at the same time sufficiently high to withstand the metallostatic pressure of the molten metal. The optimal value of the bending strength was considered to be about 1.5 MPa.

Therefore, the sand mixture selected for further studies had the following composition:

- medium size silica sand from the Grudzeń Las mine - 100 parts by weight,
- water glass grade R 145 - 2.5 parts by weight,
- Flodur 3 - 10% relative to the water glass content.

For the selected sand mixture composition, scanning images were made, allowing for an evaluation of the effectiveness of the sand grains bonding. Microscopic examinations were carried out using a SCIOS FEI scanning electron microscope. The obtained images are shown in Figure 3. Analyzing the scanning images (Fig. 3a-c), it can be seen that the binder fully covers the base sand grains, instead of forming only bridges that connect separate grains.

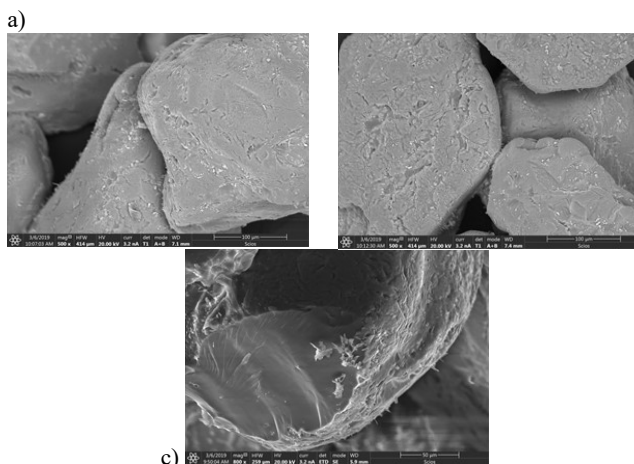


Fig. 3. Scanning images of the sand mixture samples containing 2.5 parts by weight of binder and hardener in an amount of 10% relative to the amount of binder: a, b - 500x, c - 800x

3. Casting process

From the sand mixture of the selected composition, a foundry mould was made in a wooden flask and, as a next step, castings were poured by both traditional technique and modified ablation process.

Melting for ablation casting was carried out in a device for moulding sand removal from the casting and subsequent casting cooling, installed at the Foundry Research Institute and protected by Polish patent No.P.404518. A scheme of this device is shown in Figure 4.

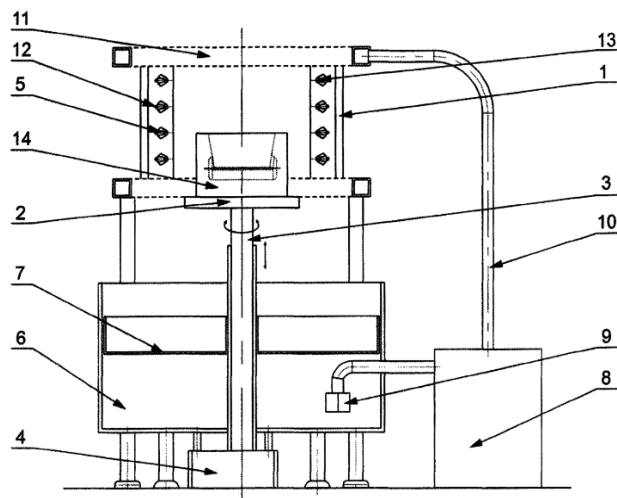


Fig. 4. Scheme of the device for moulding sand removal from casting and casting cooling, where: 1 - chamber, 2 - movable work table, 3 - lift, 4 - drive system, 5 - nozzles, 6 - tank for flowing liquid cooling medium, 7 - basket collecting moulding sand from broken mould, 8 - pump, 9 - filter, 10 - high pressure pipes for feeding liquid coolant to nozzles, 11 - distribution bar, 12 - joints, 13 - deflectors, 14 - mould [16]

Mould for ablation casting was prepared in a specially designed wooden flask shown in Figure 5. The design of the mould enables making castings with dimensions that allow determining the strength properties and microstructure. The subsequent stages of mould making are shown in Figure 6 a-c.

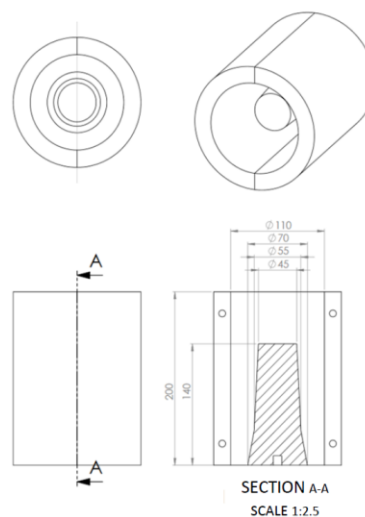


Fig. 5. Scheme of wooden flask for mould making



Fig. 6. Individual stages of mould making for ablation casting: a - wooden flask, b - mould resting in the flask, c - mould ready for pouring

The mould was mounted in the chamber of the device and the movable work table was lowered. The mould was poured with an AlSi7Mg (AK7) alloy, which temperature was 720°C, and after 15 seconds from the moment of pouring it was rotated and water jets were activated. Movable work table was rotating with speed 40 rpm. The water jet pressure was 11 MPa and its temperature was 24°C. The mould was disintegrated after 5 minutes, and a ready cooled casting was obtained. The course of the process is

shown in Figure 7. In parallel, another mould was poured by traditional gravity technique and after cooling the casting was knocked out.

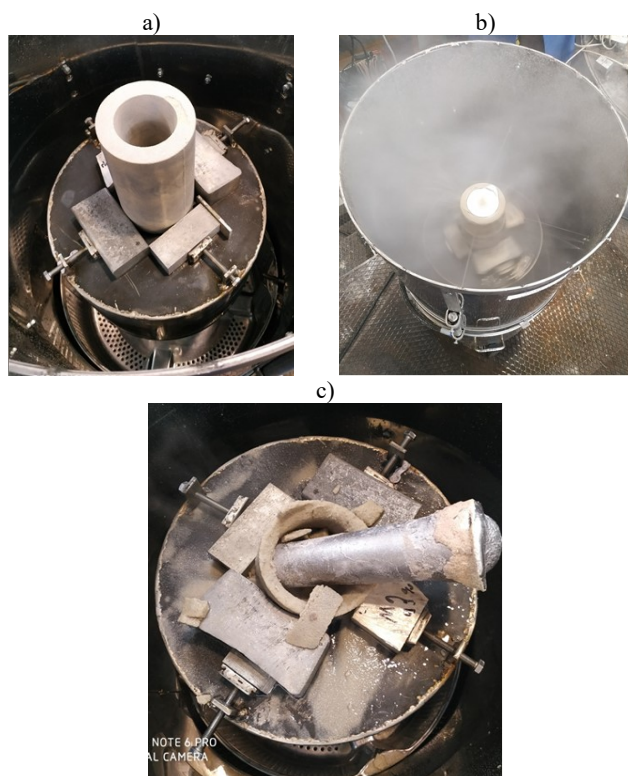


Fig. 7. The course of the modified ablation casting process, a - mould placed on the work table, b - mould cooled with water, c – view of the ready casting removed from the mould by ablation process.

4. Test results

After melting, tests were carried out on castings made by both techniques. The parameters tested included surface quality, microstructure and strength properties.

The average surface roughness R_a of the casting made by the traditional process was $8.41 \mu\text{m}$. This value increased to $12.11 \mu\text{m}$ in the casting made by the modified ablation process. The maximum deviation from the surface profile R_{max} was $74.47 \mu\text{m}$ for the casting made by the traditional process and $153.46 \mu\text{m}$ for the ablation casting. Hence it follows that the quality of the outer surface in castings made by the ablation process was inferior to that obtained by the traditional method.

The microstructure of the ready castings was examined at three levels of the casting height at a magnification of 100x (Fig. 8) and 500x (Fig. 9). Microstructure examinations were carried out on metallographic specimens etched in a 1% HF reagent using an AxioObserver Zmo10 light microscope.

Analyzing the results of structure examinations it can be noticed that under the influence of the increasing cooling rate, the interphase spacing decreases. Thanks to this, a refined and homogeneous microstructure is obtained. Moreover, in the case of ablation casting, in the middle part of casting (area No. 2), where mould ablation is the most intense, a transition of the irregular lamellar eutectic into fibrous eutectic occurs. This improves the mechanical properties of castings as further confirmed by mechanical tests carried out on standard samples. Table 1 presents the results of mechanical tests carried out on castings.

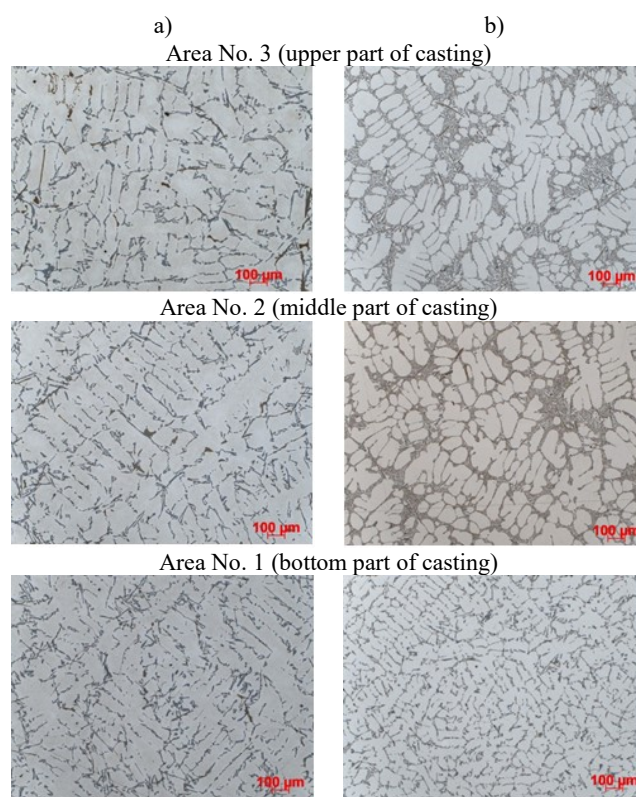


Fig. 8. Sampling sites and as-cast microstructures at 100x magnification; a - casting made by the traditional process, b - casting made by the modified ablation technology

a)

b)

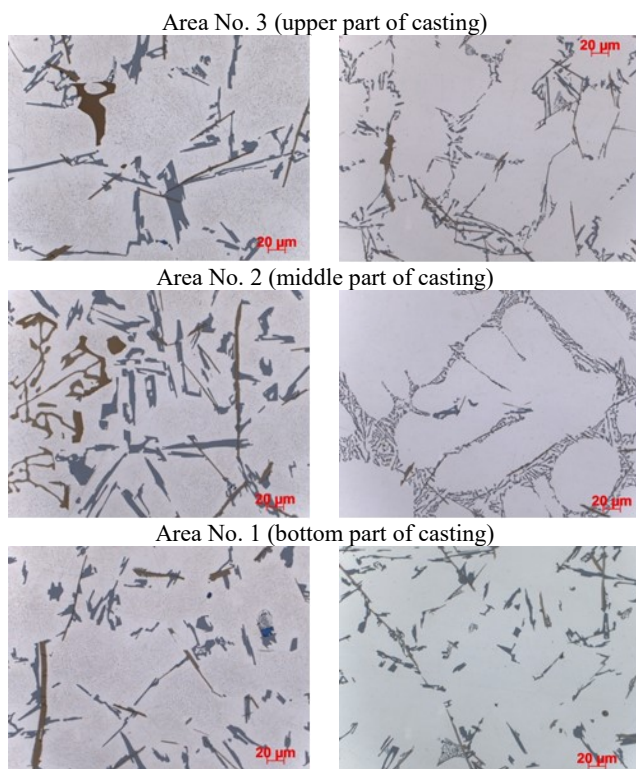


Fig. 9. Sampling sites and as-cast microstructures at 500x magnification: a - casting made by the traditional process, b - casting made by the modified ablation technology

Table 1.
The results of mechanical tests carried out on castings

Casting designation	d_0 mm	$R_{p0.2}$ MPa	R_m MPa	A %	Z %
Casting cooled and solidifying in the traditional process	5	36	101	4,2	1,1
Casting made by the modified ablation technology	5	39	129	4,2	1,6

5. Conclusions

Analysis of the research results and literature review leads to the following conclusions:

- Even with a low binder content, the use of Floster S technology allows obtaining a moulding sand mixture with optimal strength necessary for the ablation casting process.
- Castings made by the ablation technology are characterized by poor surface quality. The surface roughness is by 30% higher than in the castings made by the traditional process.
- An increase in the cooling rate of casting reduces the interdendritic spacing, thanks to which a refined and homogeneous microstructure is obtained. In the most intensively cooled area of the casting, the irregular lamellar eutectic is transformed into fibrous eutectic. Changed

morphology of primary eutectic silicon into a fine fibrous eutectic same as in casting modified by the addition of Na or Sr.

- Ablation casting technology improves the mechanical properties of castings. The tensile strength increases from 101 MPa to 129 MPa, i.e. by about 30%.

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Research on ablation casting technology for aluminium alloys

References

- [1] Grassi, J.R., Campbell, J. (2008). US Patent No. 20080041499 A1. Washington, D.C.: U.S. Patent and Trademark Office.
- [2] Izdebska-Szanda, I., Angrecki, M. & Palma, A. (2015). Selection of technology for a modified ablation casting method. *Prace Instytutu Odlewnictwa*. LV(2), 55-66. DOI: 10.7356/ioid.2015.08. (in Polish).
- [3] Weiss, D., Grassi, J., Schultz, B. & Rohatgi, P. (2011). Testing the limits of ablation. Ablation of Hybrid Metal Matrix Composites. *AFS Proceedings*. 1-7.
- [4] Motonews (2019, June). Honda NSX - a unique drive and body structure. Retrieved February 21, 2019, from <https://www.motonews.pl/autoblog/43905-honda-nsx-unikalna-jednostka-napedowa.html>. (in Polish).
- [5] Taghipourian, M., Mohammadaliha, M., Boutorabi, S.M. & Mirdamadi, S.H. (2016). The effect of waterjet beginning time on the microstructure and mechanical properties of A356 aluminium alloy during the ablation casting process. *Journal of Materials Processing Technology*. 238, 89-95.
- [6] Hosadyna-Kondracka, M., Major-Gabryś, K., Kamińska, J., Grabarczyk, A. & Angrecki, M. (2018). Moulding Sand with Inorganic Cordis Binder for Ablation Casting. *Archives of Foundry Engineering*. 18(4), 110-115.
- [7] Bohlooli, V., Shabani Mahalli, M. & Boutorabi, S.M.A. (2013). Effect of Ablation Casting on Microstructure and Casting Properties of A356 Aluminium Casting Alloy. *Acta Metallurgica Sinica*. 26(1), 85-91.
- [8] Dudek, P., Fajkel, A., Reguła, T. & Bochenek, J. (2014). Research on ablation casting technology for aluminium alloys. *Prace Instytutu Odlewnictwa*. LIV/2, 23-35. DOI: 10.7356/ioid.2014.06. (in Polish).
- [9] Lewandowski, J.L. (1997). *Materials for foundry molds*. Kraków: Wydawnictwo Naukowe AKAPIT. (in Polish).
- [10] Zych, J. (2005). Optimization of mold technology based on water-cured esters. *Przegląd Odlewnictwa*. 55(12), 789 -792, (in Polish).
- [11] Baliński, A. et al. (2003). *21st century founding. Current state and development trends of casting technology*. Kraków: Wydawnictwo Instytutu Odlewnictwa. (in Polish).
- [12] Baliński, A. (2000). *Selected problems of molding sand technology with inorganic binders*. Kraków: Wydawnictwo Instytutu Odlewnictwa. (in Polish).

- [13] Major-Gabryś, K. (2016). *Foundry sands and core environmentally friendly*. Katowice-Gliwice: Wydawnictwo Archives of Foundry Engineering. (in Polish).
- [14] Holtzer, M. (2013) Directions of molding sand development and core with inorganic binders in the aspect of reducing negative impact on the environment. *Archives of Foundry*. 2(3), 50-56. (in Polish).
- [15] Wilkosz, B. (1986). The bonding mechanism of moulding sands in Floster S process. *Przegląd Odlewnictwa*. 1, 15-18, (in Polish).
- [16] Dudek, P., Fajkiel, A., Saja, K., Reguła, T., Bochenek, J. (2013). PL Patent No. 222130 B1.