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POSSIBILITIES OF RECLAMATION MICROWAVE-HARDENED MOLDING SANDS WITH WATER GLASS

MOŻLIWOŚCI REGENERACJI UTWARDZANYCH MIKROFALAMI MAS FORMIERSKICH ZE SZKŁEM WODNYM

The paper presents results of a research on identifying opportunities for effective reclamation of waste molding sand with water-glass, hardened by microwave heating. The molding sand applied in the tests was prepared with use of selected type 145 of sodium water-glass. The sand was sequentially processed by microwave hardening, cooling, thermal loading to 800°C, cooling to ambient temperature, crushing and mechanical reclamation. These stages create a closed processing loop. After each cycle, changes of tensile strength and bending strength were determined. Results of the study show that it is possible to activate surface of high-silica grains of waste foundry sand hardened with microwaves, provided that applied are appropriate processing parameters in successive operation cycles.

Keywords: molding sand, water-glass, reclamation, microwave heating, hardening

W pracy przedstawiono wyniki badań nad określeniem możliwości prowadzenia skutecznej regeneracji zużytych mas formierskich ze szkłem wodnym utwardzanych w procesie nagrzewania mikrofalowego. Przeznaczoną do badań masę, sporządzoną z wybranym szkłem wodnym sodowym gatunku 145, poddawano kolejno procesom: utwardzania mikrofalowego, studzenia, obciążaniu termicznemu do temperatury 800°C, studzenia do temperatury otoczenia, rozkruszania i regeneracji mechanicznej. Opisane procesy tworzyły jeden zamknięty cykl przerobu zużytej masy. Po każdym kolejnym cyklu przerobu masy określano zmianę wytrzymałości na rozciąganie i zginanie. Analizując wyniki przeprowadzonych badań stwierdzono, że istnieje możliwość aktywacji regeneratu zużytej masy formierskiej ze szkłem wodnym, utwardzanej w procesie nagrzewania mikrofalowego, pod warunkiem zastosowania odpowiednich parametrów jej przygotowania, odbywającego się w kolejnych cyklach eksploatacji.

1. Introduction

The foundry industry belongs to those industries where consumed are significant amounts of natural raw materials. Thus, the foundry practice intensively affects the environment and often, contributing to its degradation, causes irreversible changes of the surroundings. The group of natural raw materials used in masses for manufacture of castings includes aggregates used for molding and core sands. Due to its generally easy availability and low buying cost, the material most often used for matrix of sandmixes is high-silica sand.

The highly topical and important issue is reducing exploitation of deposits of natural raw materials from that new molding sands are produced. Currently, continued are intensive works on improving the methods of recovery and reuse of molding sands. These methods are commonly called the reclamation process that consists in separating the binding material (binder), chemically and thermally reacted to different degrees, from matrix grains of the waste molding sand. The separation process can be carried-out in various ways, depending on kind of the used binder and requirements imposed to the recovered matrix. Separating the film of hardened and

overheated binding material present on the surface of matrix grains can be performed dry or wet (generally using water) [1]. From among the so-far developed methods of reclaiming sand matrix, the most commonly used is mechanical, pneumatic, thermal, wet and combined reclamation [2]. Considering the well ecologically grounded strong emphasis put on searching new molding sands containing environment-friendly binders [3, 4], researchers are always interested in sandmixes containing eco-friendly water-glass [5, 6]. This inorganic binder used in foundry industry is characterised by low cost and small harmfulness for the environment and human health. Its disadvantages include, first of all, worse knock-out properties, as well as difficult processes of cleaning the castings of waste molding sand and separating the film of hardened glassy sodium silicate from the matrix [7].

Condition of waste water-glass containing sandmix does not allow its repeated use without carrying out the expensive reclamation process. Waste molding sand shown exemplarily in Fig. 1, belonging to the waste group No. 10 09 or 10 10, should be, according to the ordinance of the Council of Ministers of 14th October 2008, in whole directed to waste dumps with no reclamation process [8]. Such a procedure results in

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increasing degradation of the environment, each year feeding waste dumps with 250 to 350 thousand tons of waste molding sand [1].

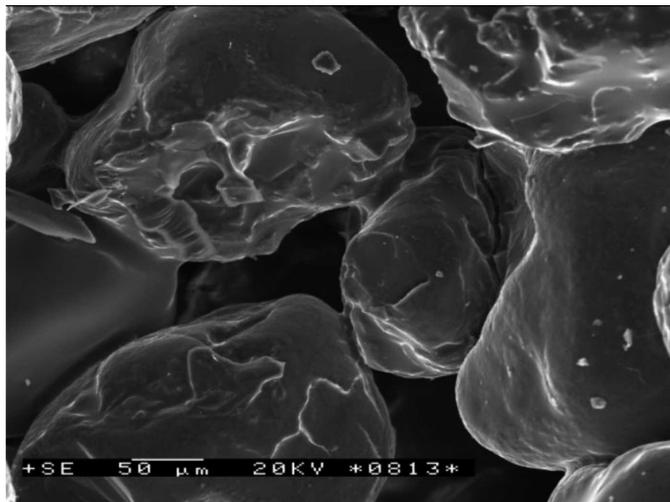
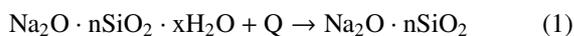


Fig. 1. Film of glassy sodium silicate covering grain surfaces of high-silica matrix of core sand used in manufacture of cast-steel castings

From among the methods of improving knock-out properties of molding sands containing hydrated sodium silicate, mentioned can be using special additives [9, 10] or limiting the content of a binder in molding sand [11], supported by advanced hardening process [5, 11-13]. Modern way of manufacturing casting molds and cores of water-glass containing sandmixes, which is hardening in the microwave heating process, changes the previous classification of this binder. As results from analysis of previous research works, this way of hardening permits obtaining very good mechanical and technological parameters with considerably limited content of the binder, being 1.5 % only [11, 13].

It is supposed that water-glass is subject to dehydration in the microwave hardening process and the binder is transformed to anhydrous glassy silicate film binding matrix grains, which can be written by the following chemical equation [2]:



where n and x are stoichiometric coefficients, Q – heating process.

It results from literature data that partial inversion of this reaction is also possible, because of hydrophilic nature of water-glass, which is applied in the process of wet reclamation of chemically hardened self-hardening sandmixes [1, 14]. However, unknown is the effect of high temperature on the binder of a sandmix hardened in the microwave process.

2. Objective of the research

The preliminary research was aimed at developing a method of reclaiming microwave hardened molding sands containing water-glass. Results of the reclamation processes will be evaluated using selected mechanical and technological criteria of the sandmix newly prepared with use of reclaimed medium high-silica matrix. The waste molding sand will be

subject to mechanical reclamation [1, 7, 15] with additionally introduced elements of wet reclamation in order to weaken cohesive and adhesive bonds of the glassy film of hardened and overheated binder.

3. Results of the research

Before starting the examinations, on the grounds of literature data [1, 2, 14, 15] selected were possible reclamation operations, as shown in details in the diagram, see Fig. 2. The entire reclamation process was divided into cyclically performed stages. Each successive cycle starts from “Stage I” containing basic operations of the actual reclamation carried-out on preliminarily disintegrated waste molding sand. Figure 3 shows combined measurements of strength values R_g^U and R_m^U of the sandmix examined at “Stage III”, prepared from the reclaimed material according to the prescriptions described at “Stage II”. The cycle “0” marked on the abscissa axis describes parameters of fresh, microwave hardened sandmix prepared from medium high-silica sand with an addition of 1.5% hydrated sodium silicate grade 145. The presented cycle of processing waste sandmix was to show whether it is possible to invert the dehydration process (described by the equation 1) of the binder subject to the innovative microwave heating followed by thermal loading at 800°C.

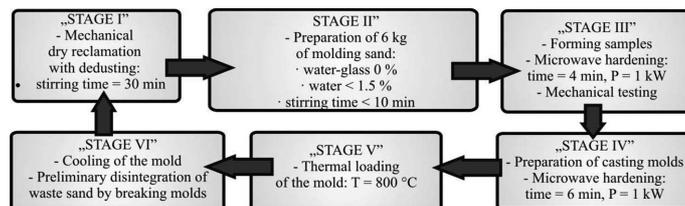


Fig. 2. Schematic presentation of one processing cycle of waste molding sand carried-out in laboratory conditions

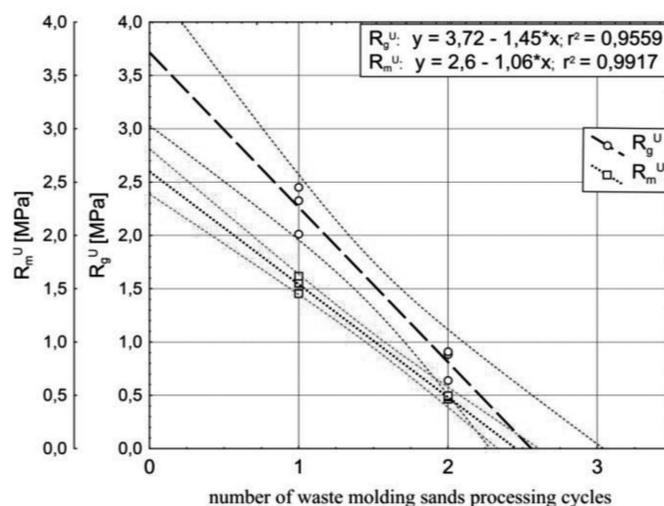


Fig. 3. Diagram of permeability and strength changes controlled at “Stage III” of each processing cycle of waste molding sand

As results from changes of parameters of the sandmix containing reclaimed high-silica sand, the examinations should be stopped just after 1st reclamation cycle because of significant decrease of bending strength R_g^U and tensile strength

R_m^U . However, it should be noted that the applied extended process of mechanical reclamation in a mixer performing the grinding action for 30 minutes, accompanied by removing the powdery fraction, "activated" the not completely removed glassy film of sodium silicate. Introducing to high-silica matrix being processed ca. 1.0% of water at "Stage II" resulted in repeated wetting of the undeleted glaze and gave back the examined sandmix ca. 40% of its initial binding properties, see Fig. 3. This can evidence the possibility of occurrence of the reversible process, described before in literature but not observed in practice, consisting in repeated hydration of water-glass microwave hardened and overheated at high temperature.

Considering the above-described findings, an attempt was made to modify parameters of dry reclamation of high-silica matrix at "Stage I", consisting in reducing the time of disintegrating waste molding sand till the moment when pellets were no longer observed. At the additional "Stage II" introduced were also elements of wet reclamation, as shown in Fig. 4.

It was pre-assumed that, by proper selection of process parameters and introduction of specified, small amounts of "activating" components, the microwave-hardened sandmix containing water-glass grade 145 can be treated as "refreshed" circulating sand (Fig. 5), which is of great importance from economical, environmental and technological points of view.

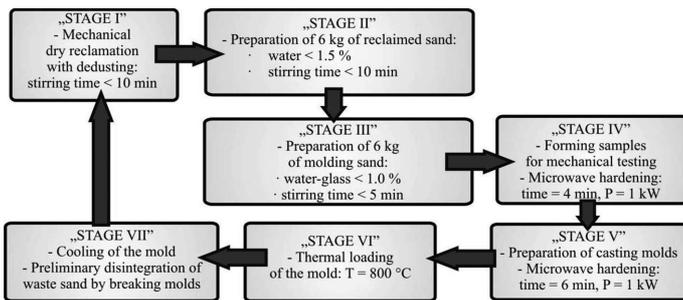


Fig. 4. Schematic presentation of modified processing cycle of waste molding sand carried-out in laboratory conditions

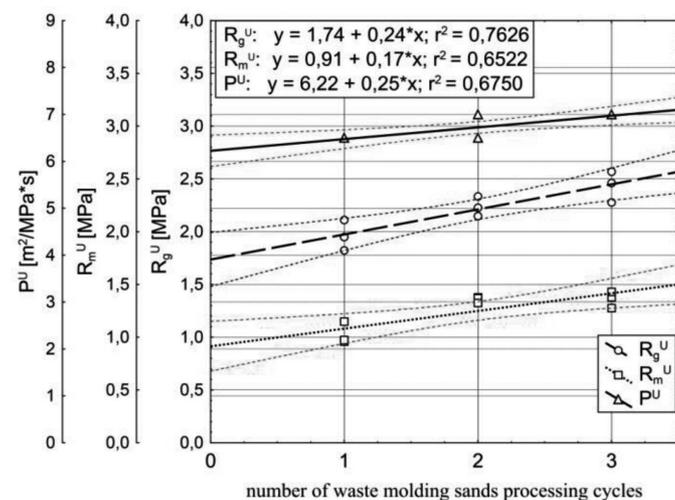


Fig. 5. Diagram of permeability and strength changes controlled at "Stage IV" of three processing cycles of waste molding sand

The examination results obtained after 3 cycles of reclamation indicate a possibility to conduct the reclamation process of sandmixes composed of high-silica matrix and

water-glass grade 145 hardened with microwaves in such a way that, by proper selection of reclamation parameters, sequence of operations and quantities of activating components, they could become circulating sands. The operations aimed at "activating" the film of hardened binder left on the surface of reclaimed matrix did not deteriorate permeability of the sandmix, see Fig. 5. Changes of the parameters R_g^U and R_m^U indicate that the suggested way of reclamation did not impair the linking bridges newly created from overheated binder layer and small amount of fresh water-glass.

4. Conclusions

Analysis of the results of laboratory examinations on possibility to reclaim waste molding sands containing water-glass, hardened with microwaves, with use of available equipment for preparing and controlling molding and core sands, indicates the following:

- Possible is "activation" of a hydrophilic binder, as hydrated sodium silicate, after overheating the molding sand to 800°C, provided that dry and wet reclamation parameters are correctly selected.
- Introducing small quantities of fresh "activating" components creates a possibility to stabilize mechanical and technological parameters determined for new sandmix containing high-silica sand and water-glass grade 145.
- Operations of dry reclamation combined with removing powdery fraction should be carried-out only to the moment of disintegration of the waste molding sand, agglomerated after the knocking-out operation.
- Operations of wet reclamation following those of dry reclamation should be carried-out on reclaimed high-silica sand subject to grinding in suitable mixing devices.
- Examinations of influence of each reclamation cycle on topography and parameters of surface of matrix grains after dry reclamation and after microwave hardening of the refreshed sandmix should be complemented with SEM observations and analysis of changes of wear resistance.
- The research should be extended by subsequent cycles of sandmix reclamation, during that controlled should be also change of abrasion resistance and pH of the reclaim.
- Beside clear economic advantages, the method of hardening a binder in the microwave heating process, tested on foundry environment, permits giving the water-glass containing sandmixes status of circulating sands for at least 3 reclamation cycles, thus reducing consumption of fresh sands and consequently improving condition of natural environment.
- Research works on possibilities to reclaim molding sands by "activating" overheated waste binder should be continued for other grades of sodium water-glass and for the cases of larger thermal loading (higher temperature) of sandmixes designed for casting molds and cores.

REFERENCES

- [1] J. Dańko, R. Dańko, M. Łucarz, Processes and equipment for reclamation of matrix of waste molding sands, Scientific Publishing House Akapit, Kraków 2007 (in Polish).

- [2] J.L. Lewandowski, Materials for casting molds, Scientific Publishing House Akapit, Kraków 1997 (in Polish).
- [3] B. Grabowska, M. Holtzer, R. Dańko, M. Górny, A. Bobrowski, E. Olejnik, New BioCo binders containing biopolymers for foundry industry, *Metallurgija* **52**, 1, 47-50 (2013).
- [4] S.M. Dobosz, K. Major-Gabryś, Biopolymers as 4th generation binders of molding sands, *Archives of Mechanical Technology and Automation*, Poznań **30**, 1, (2010) (in Polish).
- [5] Wang Huafang, Fan Zitian, Liu Fuchu, Li Xuejie, Preliminary study on humidity resistance of sodium silicate sand hardened by microwave heating coated with eutectic lithium salts, *Zhuzao/Foundry* **61** (4), (2012).
- [6] I. Izdebska-Szanda, A. Balinski, New generation of ecological silicate binders, *Procedia Engineering* **10**, 887-893 (2011).
- [7] J. Danko, J. Kaminska, M. Skrzynski, Reclamation of spent moulding sands with inorganic binders in the vibratory reclaimer Regmas, *Archives of Metallurgy and Materials* **58**, 3 (2013).
- [8] J. Dańko, M. Holtzer, Methods of reducing foundry wastes and way of their management. Scientific Publishing House Akapit, Kraków 2010 (in Polish).
- [9] S. Dobosz, P. Jelínek, K. Major-Gabryś, Development tendencies of molding and core sands, *China Foundry* **8**, 4, 438-446 (2011).
- [10] A. Kmita, B. Huttera, Water glass modification and its impact on the mechanical properties of moulding sands, *Archives of Foundry Engineering* **13**, 2, 81-84 (2013).
- [11] Wang Jina, Fan Zitian, Zan Xiaolei, Pan Di, Properties of sodium silicate bonded sand hardened by microwave heating, *China Foundry* **6**, 3, 191-196 (2009).
- [12] B. Grabowska, M. Holtzer, Structural examination of the cross-linking reaction mechanism of polyacrylate binding agents, *Archives of Metallurgy and Materials* **54**, 2, 427-437 (2009).
- [13] M. Stachowicz, K. Granat, D. Nowak, Dielectric hardening method of sandmixes containing hydrated sodium silicate, *Metallurgija* **52** (2), 169-172 (2013).
- [14] Wang Huafang, Fan Zitian, Yu Shaoqiang, Liu Fuchu, Li Xuejie, Wet reclamation of sodium silicate used sand and biological treatment of its wastewater by *Nitzschia palea*, *China Foundry* **9**, 1, 34-38 (2012).
- [15] R. Dańko, Development of energetic model for dry mechanical reclamation process of used foundry sands, *International Journal of Cast Metals Research* **20**, 4, 228-232 (2007).